



Biological Assessment Report

Clear Creek Barry and Lawrence Counties

2016 - 2017

Prepared for:

**Missouri Department of Natural Resources
Division of Environmental Quality
Water Protection Program
Water Pollution Control Branch**

Prepared by:

**Missouri Department of Natural Resources
Division of Environmental Quality
Environmental Services Program
Water Quality Monitoring Section**

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1.0 Introduction

At the request of the Missouri Department of Natural Resources (**MoDNR**) Water Protection Program (**WPP**), the Environmental Services Program (**ESP**) Water Quality Monitoring Section (**WQMS**) conducted a biological assessment of Clear Creek (Water Body ID 3239) located in Barry and Lawrence counties, Missouri. A two-mile reach of Clear Creek downstream of the Monett Wastewater Treatment Facility (**WWTF**) was originally added to the 303(d) list in 1998 for high levels of biochemical oxygen demand (**BOD**), non-filterable residue (**NFR**), and ammonia. In 1999, a Total Maximum Daily Load (**TMDL**) was approved by U.S. Environmental Protection Agency (**EPA**) that addressed the high levels of BOD, NFR, and ammonia in Clear Creek (MoDNR 1999). In 2004, nutrients and dissolved oxygen (**DO**) were added as impairments to the reach of Clear Creek on the 1998 303(d) list. A TMDL that addresses nutrients and low DO has not yet been completed.

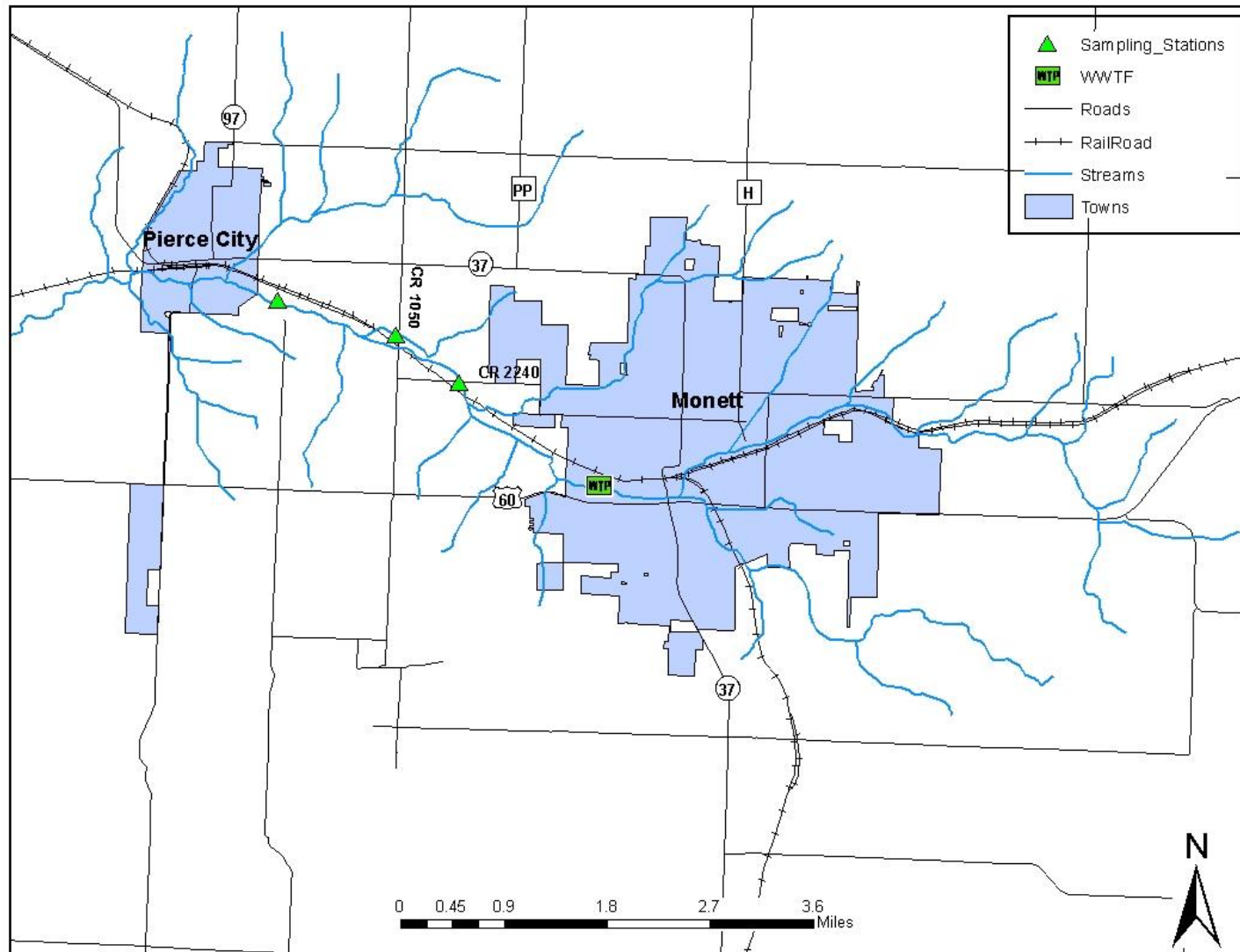
1.1 Study Area/Justification

Clear Creek, a tributary of Shoal Creek, originates in northern Barry County near Monett, Missouri (Figure 1). Clear Creek is listed in the Missouri Water Quality Standards (**WQS**, MoDNR 2014b) as a losing stream upstream of the Monett WWTF. The first two miles of Clear Creek below the Monett WWTF are classified as a class “C” stream and the next nine miles downstream to its confluence with the Shoal Creek are classified as class “P.” According to the WQS, the designated uses for the Class C segment of Clear Creek are “warm water aquatic life protection, human health/fish consumption, livestock and wildlife watering, irrigation, secondary contact recreation, and class B whole body contact recreation.”

Biological assessment studies were conducted in 1997 and 2000 (MoDNR 2000). A total of three stations were sampled, with two stations being sampled in each study. The same upstream station was used during both studies, but a different location was used as the downstream station in 2000. Both studies showed macroinvertebrate community impairment at all stations compared to the Ozark/Neosho Ecological Drainage Unit (**EDU**) biological criteria (Table 10).

Clear Creek was originally placed on the 303(d) list because the Monett WWTF had a history of mechanical problems and intermittent flows of high BOD influent from food processing industries within the city that led to frequent violations of National Pollutant Discharge Elimination System (**NPDES**) permit #MO0021440 (MoDNR 1999). Both BOD and NFR frequently had monthly averages of 30 mg/L. By comparison, the permitted weekly average for BOD is 15 mg/L and 20 mg/L for NFR. In 1988, the Missouri Attorney General’s Office took legal action against the City of Monett because of chronic non-compliance of the NPDES permit. In addition to problems with BOD and NFR, Clear Creek had WQS violations for DO and ammonia for 2-3 miles when the WWTF was operating normally and severe water quality problems for several more miles when it was not operating properly. A water quality survey by MoDNR in 1978 found that DO ranged from 2-3 mg/L two miles downstream of the outfall, ammonia levels of 7.5-11 mg/L just below the outfall and 2-3 mg/L two miles downstream (MoDNR 1999). Another MoDNR survey conducted in July and September 1985 found DO levels that were at or slightly below 2 mg/L one mile downstream and 2-2.5 mg/L two miles downstream. The same study found ammonia levels of 2-3 mg/L just downstream of the discharge and about 1.5-2 mg/L one mile downstream (MoDNR 1999). More recently, a fish kill

Figure 1
Map of Clear Creek and Sampling Stations



affecting more than five stream miles in May 2014 was caused when Tyson Foods, Inc. discharged a solution of Alimet[®] (a livestock feed ingredient) to the Monett WWTF, which killed the plant's denitrifying microbes. This resulted in WWTF discharges in Clear Creek that had high levels of ammonia. At least 108,809 fish and crayfish valued at \$130,988.26 died during this incident (MDC 2016).

1.2 Purpose

The purpose of this study is to assess Clear Creek to determine the condition of the macroinvertebrate community two years after the 2014 fish kill and compare the results to earlier biological assessment studies.

1.3 Objectives

- 1) Determine if the macroinvertebrate community in Clear Creek is impaired compared to biological criteria developed from reference stream data in the Ozark/Neosho EDU.
- 2) Assess the habitat quality of Clear Creek.

1.4 Tasks

- 1) Conduct a bioassessment of the Clear Creek macroinvertebrate community at three sampling stations during the fall 2016 and spring 2017 sampling seasons.
- 2) Collect water samples and water quality field measurements at three Clear Creek sampling stations during the fall 2016 and spring 2017 sampling seasons.
- 3) Conduct a habitat assessment at the sampling stations to ensure comparability of aquatic habitats.

1.5 Null Hypotheses

- 1) The macroinvertebrate community will not differ among longitudinally separate reaches of Clear Creek.
- 2) The macroinvertebrate assemblage of Clear Creek samples will be similar to the Ozark/Neosho EDU wadeable/perennial stream biological criteria.
- 3) Physicochemical water quality from Clear Creek will meet the WQS of Missouri (MoDNR 2014b).
- 4) Physicochemical water quality will not differ among longitudinally separate reaches of Clear Creek.
- 5) Stream habitat at the Clear Creek sampling stations will be similar to Jones Creek, a candidate reference stream in the Ozark/Neosho EDU.

2.0 Methods

Carl Wakefield, Ken Lister, and Rachel Heth of the Missouri Department of Natural Resources, Division of Environmental Quality, Environmental Services Program, Water Quality Monitoring Section conducted this study.

2.1 Study Timing

Macroinvertebrate and water samples were collected at the Clear Creek stations during the fall 2016 and spring 2017 sampling seasons. Fall sampling was conducted on September 21, 2016, and spring sampling was conducted on March 15, 2017.

2.2 Station Descriptions

The study area and sampling locations for the Clear Creek biological assessment study are shown in Figure 1. The Clear Creek study sites and their locations are listed below from downstream to upstream.

Clear Creek #1 – Lawrence County, approximately 0.3 miles upstream of Pierce City Park. Legal description is NE 1/4, Sec. 28, T. 26 N., R. 28 W. Geographic coordinates are UTM zone 15, 411769 Easting, 4088610 Northing.

Clear Creek #2 – Lawrence County, upstream of County Road 1050. Legal description is SW 1/4, Sec. 26, T. 26 N., R. 28 W. Geographic coordinates are UTM zone 15, 413422 Easting, 4088142 Northing.

Clear Creek #3 – Barry County, upstream of Farm Road 2235. Legal description is NE 1/4, Sec. 35, T. 26 N., R. 28 W. Geographic coordinates are UTM zone 15, 414290 Easting, 4087499 Northing.

2.3 MoRAP Aquatic Ecological Classification

The aquatic ecological classification developed by the Missouri Resources Assessment Partnership (**MoRAP**) is a classification system that divides the aquatic resources of Missouri into distinct regions. It has seven levels of classification starting at large regions and then dividing them into smaller sub-regions (Sowa et al. 2004). The following are the seven levels of classification in hierarchical order: zone, subzone, region, aquatic sub-regions, EDU, Aquatic Ecological Systems (**AES**), and Valley Segment Types (**VST**). The levels of classification are based on biology, zoogeography, taxonomic composition, geology, soils, and groundwater connection. Some levels of the hierarchical system use geology and soils to classify, whereas other levels use biology and taxonomic composition of aquatic communities. EDU, AES, and VST are the three levels of classification that will be discussed in detail for this study.

2.3.1 Ecological Drainage Unit

The EDU is level five of the classification hierarchy and is based on geographical variation of the taxonomic composition of the level four sub-regions. An EDU is a region in which aquatic biological communities and habitat conditions can be expected to be similar. All Clear Creek sample stations were located within the Ozark/Neosho EDU.

2.3.2 Aquatic Ecological Systems

Aquatic Ecological Systems are level six of the classification hierarchy. They classify aquatic systems based on geology, soils, landform, and groundwater influence. Clear Creek is located in the Upper Spring River of the Neosho AES type (Sowa and Diamond 2006). Local relief for the Upper Spring River of the Neosho AES type is generally less than 100 feet but will occasionally approach 200 feet. Bedrock geology is Mississippian period cherty limestone that underlies deep soils that formed in this weathered cherty limestone covered with loess. Karst features are prominent with a large number of springs and sinkholes in the AES type. Surface soil textures consist of loams and silty loams that have slow to moderate infiltration rates. Streams generally carry bed loads of cherty gravel and sand. Coldwater is an important ecological feature of this AES type. Springs are abundant and often contribute in maintaining stream base flows. Historic vegetation was principally prairie with timber found along streams.

2.3.3 Valley Segment Types

Valley Segment Types are level seven of the classification hierarchy. Stream segments in the GIS stream network layer are classified using a 5-digit code. The 5-digit VST code is based on temperature regime, stream size, flow regime, geology, and relative gradient. The 5-digit VST codes and the values for the five parameters making up the codes can be found in Table 1.

2.4 Land Cover

Land cover percentages were determined using the Missouri portion of the MoRAP Thematic Mapper satellite data from 2000 to 2004. Land cover percentages were determined for the entire Ozark/Neosho EDU, Clear Creek sampling stations, and Jones Creek, a candidate reference stream in the Ozark/Neosho EDU.

2.5 Habitat Assessment

A standardized assessment procedure was followed as described for riffle/pool habitat in the *Stream Habitat Assessment Project Procedure (SHAPP)* (MoDNR 2016f). Habitat assessments were conducted at the three Clear Creek test stations and Jones Creek, a candidate reference stream. Stream habitat assessments were completed at Jones Creek on August 17, 2016, and on September 21, 2016, at Clear Creek test stations.

2.6 Biological Assessment

Biological assessments consisted of macroinvertebrate collection and physicochemical sampling for the two sample periods.

2.6.1 Macroinvertebrate Collection and Analysis

A standardized macroinvertebrate sample collection and analysis procedure was followed as described in the *Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP)* (MoDNR 2012) for riffle/pool (**RP**) streams. Three standard habitats—flowing water over coarse substrate (**CS**), depositional substrate in non-flowing water (**NF**), and rootmat (**RM**)—were collected at the sampling stations.

Table 1
 Physical Characteristics of the Sampling Reaches for Clear Creek Based on Values from the
 MoRAP Valley Segment Types (VST) Geographic Information Systems (GIS) Layer and Other
 GIS Sources

	Clear Creek #1	Clear Creek #2	Clear Creek #3
Watershed Area (mi ²)	29.2	26.9	25.5
Strahler Order	3	3	3
Link Magnitude	20	18	18
VST 5 Digit Code	22221	22221	22221
Temperature Regime	Warm	Warm	Warm
Stream Size	Creek	Creek	Creek
Flow Regime	Intermittent	Intermittent	Intermittent
Geology	Limestone	Limestone	Limestone
Relative Gradient	Low	Low	Low

Macroinvertebrate data were analyzed using two methods. The first analysis was to calculate the Macroinvertebrate Stream Condition Index (**MSCI**) using the four general biological metrics found in the SMSBPP (MoDNR 2002a, MoDNR 2012). These four biological metrics included: 1) Taxa Richness (**TR**); 2) Ephemeroptera/Plecoptera/Trichoptera Taxa (**EPTT**); 3) Biotic Index (**BI**); and 4) Shannon Diversity Index (**SDI**). These individual metrics were scored by comparing them to the biological criteria for perennial/wadeable streams in the Ozark/Neosho EDU and combined to form the MSCI. MSCI scores of 16-20 qualify as fully supporting, 10-14 are partially supporting, and 4-8 are considered non-supporting of the protection of warm water aquatic life beneficial use designation as specified in the Missouri WQS (MoDNR 2014b).

The second analysis was an evaluation of macroinvertebrate community composition using percent composition of EPTT, sensitive taxa, functional feeding groups (**FFG**), and dominant macroinvertebrate families and taxa. Comparisons of the macroinvertebrate community of Clear Creek and the BIOREF streams also were made.

2.7 Physicochemical Data Collection and Analysis

2.7.1 *In situ* Water Quality Measurements

During each sampling period, *in situ* water quality measurements were collected at each of the bioassessment sampling stations. Field measurements included water temperature (°C) (MoDNR 2018d), DO (mg/L) (MoDNR 2016b), conductivity (µS/cm) (MoDNR 2018e), and pH (MoDNR 2018c).

2.7.2 Water Chemistry

Surface water grab samples were collected and returned for analyses to ESP. Turbidity (NTU) (MoDNR 2018b) was measured and recorded in the ESP WQMS biology laboratory. Water samples were analyzed by ESP's Chemical Analysis Section for total suspended solids, chloride,

sulfate, total calcium, total magnesium, total phosphorus, ammonia-N, nitrate+nitrite-N, and total nitrogen. Procedures outlined in *Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations* (Standard Operating Procedure [SOP] MDNR-ESP-001 [MoDNR 2018a]) and *Field Sheet and Chain-of-Custody Record* (SOP MDNR-ESP-002 [MoDNR 2016a]) were followed when collecting water quality samples. Stream velocity was measured at each station using a SonTek/YSI Flow Tracker Handheld-ADV (Acoustic Doppler Velocimeter). Discharge was calculated per the methods in SOP MDNR-ESP-113, *Flow Measurement in Open Channels* (MoDNR 2015).

2.7.3 Data Analysis

Physicochemical data were examined by analyte to determine whether stations had violations of the Missouri WQS. Sampling stations that had values not in compliance with the WQS or U.S. EPA recommended reference values are discussed in the report with possible influences being identified.

2.8 Quality Assurance/Quality Control (QA/QC)

2.8.1 Field Meters

All field meters used to collect water quality parameters were maintained in accordance with the Standard Operating Procedure MDNR-ESP-213, *Quality Control Procedures for Checking Water Quality Field Instruments* (MoDNR 2016d).

2.8.2 Biological Samples

Steps to assure accuracy of organism removal from sample debris were performed consistent with those methods found in the SMSBPP (MoDNR 2012). Macroinvertebrates found in samples were identified to the lowest practicable taxonomic levels found in Standard Operating Procedure MDNR-ESP-209, *Taxonomic Levels for Macroinvertebrate Identification* (MoDNR 2016c).

2.8.3 Biological Data Entry

All macroinvertebrate data were entered into the WQMS macroinvertebrate database consistent with the Standard Operating Procedure MDNR-ESP-214, *Quality Control Procedures for Data Processing* (MoDNR 2016e).

2.8.4 Duplicate Sample Collection

Duplicate samples are collected at two randomly selected sampling stations per season for macroinvertebrates and for 10 percent of water samples. No duplicate macroinvertebrate samples or water samples were collected for this study.

3.0 Results

3.1 Land Cover

Jones Creek, a candidate reference stream in the Ozark/Neosho EDU, was used to compare stream habitat and land cover of the sampling stations to reference conditions. Clear Creek test stations had a higher percentage of impervious surface, high intensity urban, and low intensity urban compared to the overall Ozark/Neosho EDU and Jones Creek. Forested land cover, however, was lower among Clear Creek stations than the EDU and Jones Creek (Table 2 and

Figure 2). Percent grassland was higher at the test stations compared to the Ozark/Neosho EDU but was similar to Jones Creek.

3.2 Stream Habitat Assessment

Table 3 provides habitat assessment scores for the Clear Creek sampling stations. SHAPP guidance states that test stations scoring at least 75 percent of the total score of a reference station should support a similar biological community (MoDNR 2016f). Because Clear Creek stream habitat assessment scores were ≥ 75 percent of the reference score of Jones Creek, a candidate reference stream, the sampling stations should be capable of supporting a similar macroinvertebrate community.

Many of the habitat metric scores at the sampling stations were either in the optimal or suboptimal range, indicating good habitat quality. Some metrics, however, did not score as well. At Clear Creek #1, sediment deposition and vegetative protection for both banks scored in the marginal category, and bank stability for the right bank scored in the poor category. Clear Creek #2, which had the lowest stream habitat assessment score, had metric scores for channel flow status and right bank vegetative protection in the marginal category; left bank vegetative protection and riparian zone for both banks scored in the poor category. Clear Creek #2 was also located in a cattle pasture, and there was some evidence of bank destabilization caused by the cattle having access to the stream. At Clear Creek #3, sediment deposition and right bank vegetative protection scored in the marginal category, and left bank vegetative protection scored in the poor category.

Table 2
 Percent Land Cover from MoRAP Thematic Mapper Satellite Data from 2000 to 2004

Land Cover	Ozark/Neosho EDU	Jones Creek #3	Clear Creek #1	Clear Creek #2	Clear Creek #3
Impervious	2.6	0.7	3.2	3.3	3.3
High Intensity Urban	0.2	--	6.6	7.2	7.5
Low Intensity Urban	1.9	0.1	8.0	8.6	9.0
Barren/Sparsely Vegetated	0.6	<0.1	1.3	1.4	1.4
Cropland	15.2	5.2	0.9	0.9	0.9
Grassland	52.8	69.5	70.9	69.8	69.0
Deciduous Forest	20.3	19.2	7.3	7.5	7.6
Evergreen Forest	0.1	<0.1	--	--	--
Mixed Forest	<0.1	--	<0.1	<0.1	<0.1
Deciduous Woody/Herbaceous	4.8	4.8	1.6	1.1	0.9
Woody Dominated Wetland	0.9	0.2	<0.1	<0.1	<0.1
Herbaceous- Dominanted Wetland	0.2	<0.1	<0.1	<0.1	<0.1
Open Water	0.5	0.2	0.2	0.2	0.2

Figure 2
Land Cover of the Clear Creek Watershed

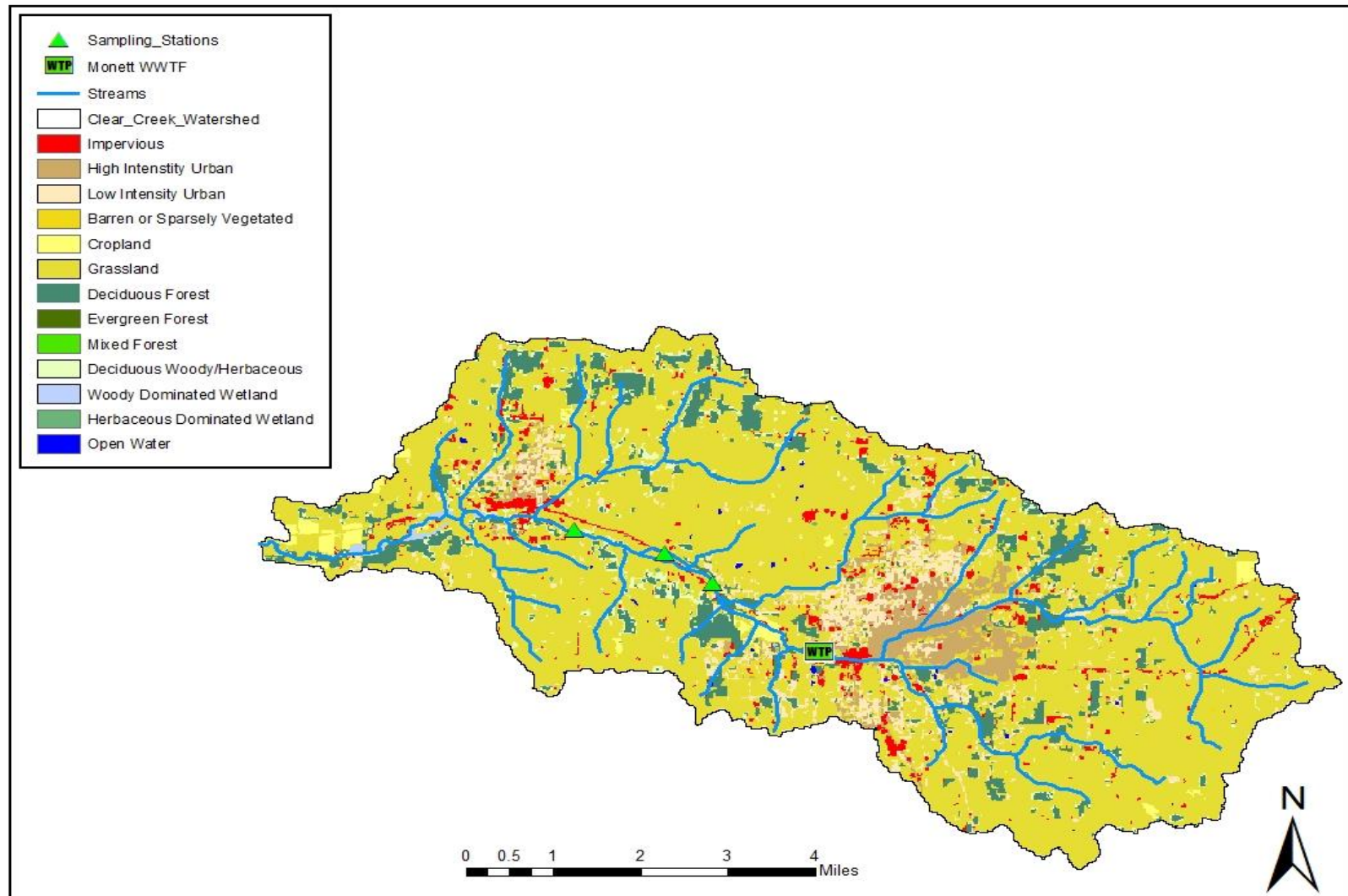


Table 3
 Predominant Category Habitat Values, Category Habitat Scores, Total Habitat Scores, and
 Percent of Reference SHAPP Values from Stream Habitat Assessments for Clear Creek
 Sampling Stations and Jones Creek, a Candidate Reference Stream

Stream Habitat Parameters	Clear Creek #1	Clear Creek #2	Clear Creek #3	Jones Creek #3
Macroinvertebrate Sample Number	16037	16036	16035	--
Stream Habitat Assessment Date	09/21/2016	09/21/2016	09/21/2016	08/17/2016
Epifaunal Substrate/Available Cover	I (17)	I (17)	II (15)	I (17)
Embeddedness	I (18)	I (18)	I (16)	I (18)
Velocity/Depth Regime	II (14)	II (14)	II (14)	II (15)
Sediment Deposition	III (10)	II (11)	III (10)	II (12)
Channel Flow Status	II (14)	III (9)	II (13)	I (18)
Channel Alteration	I (20)	I (19)	I (18)	I (18)
Riffle Quality	II (12)	II (12)	II (15)	I (17)
Bank Stability – Left Bank	I (9)	II (6)	II (7)	I (9)
Bank Stability – Right Bank	IV (2)	I (9)	II (8)	I (9)
Vegetative Protection – Left Bank	III (5)	IV (1)	IV (2)	III (4)
Vegetative Protection – Right Bank	III (3)	III (4)	III (3)	IV (2)
Riparian Zone Width – Left Bank	I (18)	IV (1)	I (9)	II (6)
Riparian Zone Width – Right Bank	I (18)	IV (2)	I (9)	III (5)
Total Habitat Score	142	123	139	150
Percent of SHAPP	94.6	82.0	92.7	--

Habitat parameter categories range from I to IV with category I = optimal, category II = suboptimal, category III = marginal, and category IV = poor. Habitat parameter scores are listed in parentheses and range from 0 to 20 except for vegetative protection and riparian zone categories, which range from 0 to 10.

3.3 Macroinvertebrate Biological Assessment

3.3.1 Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP)

MSCI scores were calculated for the Clear Creek sampling stations using riffle/pool wadeable/perennial biological criteria (Table 4). All Clear Creek stations had partially supporting MSCI scores of 10 during both sampling seasons. During both sampling seasons, EPTT scored in non-supporting range, and the other metrics scored in the partially supporting range at all stations.

Table 4
 Fall 2016 and Spring 2017 Riffle/Pool Ozark/Neosho EDU Stream Biological Criteria,
 Biological Support Categories, Biological Metric Values and Scores shown in Parentheses,
 and Macroinvertebrate Stream Condition Index (MSCI) Scores for the Clear Creek
 Sampling Stations

Station	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
Fall 2016							
Clear Creek #1	16037	42 (3)	6 (1)	6.6 (3)	2.01 (3)	10	P
Clear Creek #2	16036	43 (3)	9 (1)	6.2 (3)	2.72 (3)	10	P
Clear Creek #3	16035	39 (3)	9 (1)	6.6 (3)	2.77 (3)	10	P
Metric Score=5	If	>77	>24	<5.5	>2.97	20-16	Full
Metric Score=3	If	77-39	24-12	5.5-7.7	2.97-1.49	14-10	Partial
Metric Score=1	If	<39	<12	>7.7	<1.49	8-4	Non
Spring 2017							
Clear Creek #1	17003	53 (3)	7 (1)	6.9 (3)	2.70 (3)	10	P
Clear Creek #2	17002	45 (3)	9 (1)	6.8 (3)	2.96 (3)	10	P
Clear Creek #3	17001	48 (3)	9 (1)	6.7 (3)	2.78 (3)	10	P
Metric Score=5	If	>72	>27	<5.3	>3.01	20-16	Full
Metric Score=3	If	72-36	27-13	5.3-7.7	3.0-1.51	14-10	Partial
Metric Score=1	If	<36	<13	>7.7	<1.51	8-4	Non

MSCI Scoring Table (in light gray) developed from Ozark/Neosho EDU BIOREF samples ($n = 10$ for fall samples and $n = 12$ for spring samples); TR=taxa richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index

3.3.2 Macroinvertebrate Percent and Community Composition

The percent composition of sensitive taxa, FFG, EPTT, and the five dominant macroinvertebrate families and taxa at each station are presented in Figures 3 through 6 and Tables 5 through 8. Values in bold type represent the five dominant macroinvertebrate families and taxa for each station.

3.3.2.1 Fall 2016 Sampling Season

Percent Composition of Sensitive Taxa

Clear Creek samples had a higher percentage of taxa with BI values above 5.0 (higher tolerance to organic pollutants) than BIOREF streams (Figure 3 and Table 5). Taxa with BI values ≥ 5 averaged about 58 percent in the Ozark/Neosho BIOREF samples but ranged from about 87 to 95 percent in the Clear Creek samples. Taxa with BI ≤ 5 averaged about 42 percent in the Ozark/Neosho BIOREF samples, but values ranged from about 5.5 to 13 percent in Clear Creek.

The majority of taxa in Clear Creek samples had BI values in the moderately tolerant range (BI=5.0-7.4) and were much more abundant than reference conditions for this BI group. The percentage of tolerant taxa (BI=7.5-8.9) in Clear Creek samples was slightly higher than the Ozark/Neosho BIOREF samples. The percentage of very tolerant taxa (BI>8.9) was much higher at test stations #1 and #3 but was only slightly higher at test station #2 compared to reference conditions. Intolerant taxa (BI=2.5-4.9) and very intolerant taxa (BI<2.5) were much lower in abundance than Ozark/Neosho BIOREF samples. Very intolerant taxa were not collected in any of the Clear Creek samples.

Percent Composition of Functional Feeding Groups (FFG)

Gatherer-collectors and scrapers were abundant in all samples, and filterers were abundant in samples from two of the test stations (Figure 4 and Table 5). There were some differences in FFG abundance between the test stations and BIOREF streams. Gatherer-collectors were one of the more abundant FFGs among Clear Creek stations and were only slightly lower than reference conditions. Percent scrapers were lower at the two most upstream test stations but much higher at test station #1 compared to BIOREF streams. Percent filterers were much higher at the two upstream test stations but much lower at test station #1 than reference conditions. The percent scraper to filterer ratio was much lower at the two most upstream test stations but was much higher at test station #1 compared to BIOREF streams. Percent predator values ranged from much lower at test station #1 to slightly lower at the other two test stations compared to reference conditions. For percent shredders, values were slightly lower at test stations #1 and #2 but much higher at test station #3 compared to the Ozark/Neosho EDU BIOREF streams.

EPT Metrics

Compared to reference conditions, the Clear Creek #1 sample had a much lower percent EPTT, but this metric was higher at the other two test stations (Table 5). Percent Ephemeroptera and Trichoptera was much lower at test station #1 but was slightly higher for Ephemeroptera and much higher for Trichoptera at the other two test stations compared to BIOREF streams. Plecoptera were found in low abundance in BIOREF fall samples, but they were absent in Clear Creek samples.

Figure 3
 Percent of Taxa by Biotic Index Range, Fall 2016

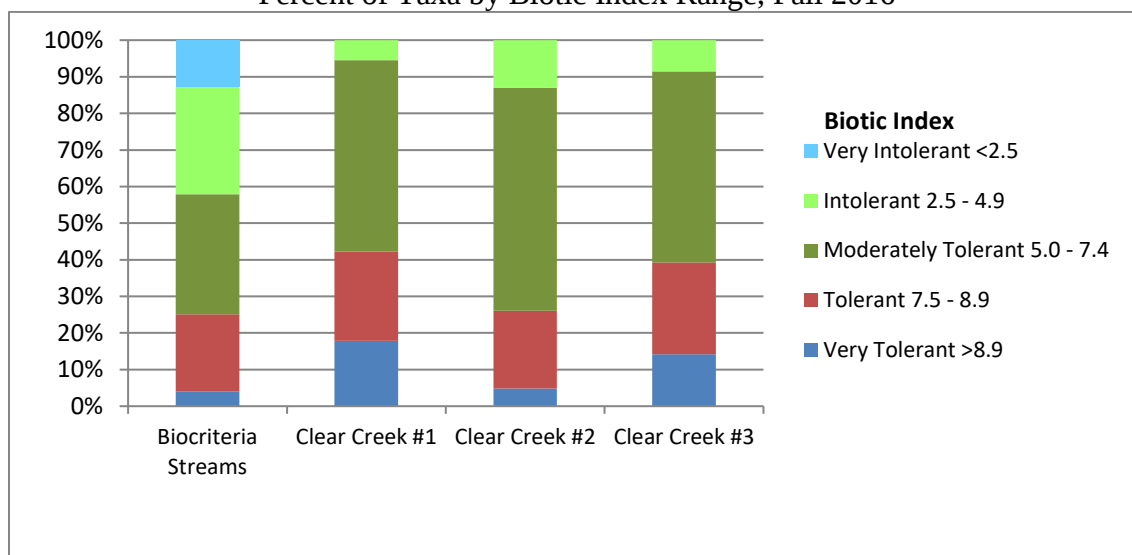


Figure 4
 Percent of Taxa by Functional Feeding Group, Fall 2016

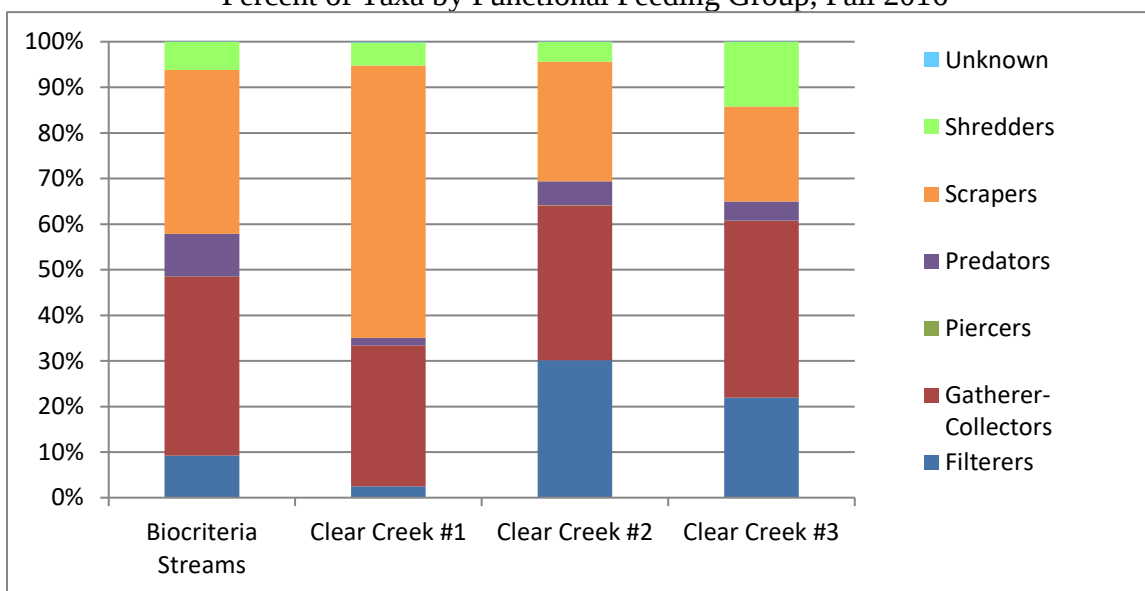


Table 5

Biological Metric Values for Sensitive Taxa, Functional Feeding Groups (FFG), and EPTT Metrics at the Biological Criteria Reference Samples and Clear Creek Study Stations, Fall 2016

Variable-Station	Ozark/Neosho Biocriteria Reference Data	Clear Creek #1	Clear Creek #2	Clear Creek #3
Sample Number		16037	16036	16035
Sensitive Taxa				
% Biotic Index >8.9	4.0	17.9	4.8	14.2
% Biotic Index 7.5-8.9	21.1	24.4	21.3	25.1
% Biotic Index 5.0-7.4	32.8	52.3	60.9	52.3
% Biotic Index 2.5-4.9	29.4	5.5	13.0	8.5
% Biotic Index <2.5	12.7	--	--	--
Functional Feeding Groups				
% Filterers	9.2	2.5	30.2	24.8
% Gatherer-Collectors	39.3	30.9	34.0	30.8
% Predators	9.3	1.7	5.2	4.8
% Scrapers	35.9	59.8	26.3	23.5
% Shredders	6.2	5.0	4.3	16.0
% Piercers	<0.1	--	0.1	0.1
% Unknown	<0.1	0.2	0.1	0.1
Scraper/Filterer Ratio	3.9	24.1	0.9	0.9
EPT Metrics				
% EPTT	37.5	7.3	48.9	43.2
% Ephemeroptera	23.9	5.1	24.3	24.7
% Plecoptera	2.1	--	--	--
% Trichoptera	11.5	2.2	24.6	18.5

Biocriteria stream data values are average percent ($n = 10$).

Macroinvertebrate Community Composition

Chironomids and riffle beetles (Elmidae) were the two dominant macroinvertebrate families found in Clear Creek fall samples (Table 6). Percent Chironomidae was higher at Clear Creek #2 compared to reference conditions, and chironomids made up a much higher percentage of Clear Creek #1 and #3 samples. *Dicrotendipes* and *Polypedilum illinoense* group were the two most common chironomids in Clear Creek samples and were much more abundant than BIOREF streams. *Dicrotendipes* was very abundant in Clear Creek #1, and *P. illinoense* group was very abundant in Clear Creek #3. *Stenelmis* was the only riffle beetle (Elmidae) taxon present in Clear Creek samples. Although *Stenelmis* was common in all Clear Creek samples, this genus was especially abundant at Clear Creek #1.

Several other taxa were also common in one or more of the Clear Creek samples. The hydropsychid caddisfly *Cheumatopsyche* was more abundant than reference conditions at Clear Creek #2 and #3, and the mayfly *Caenis latipennis* was more abundant than BIOREFs at all Clear Creek stations. Compared to BIOREF samples, the mayfly *Baetis* and caddisfly *Chimarra* were more abundant at test station #2, the snail *Physella* was more abundant at Clear Creek #1, and the baetid mayfly *Fallceon* was more abundant at Clear Creek #3. The water penny *Psephenus herricki* was one of the more abundant taxa in all Clear Creek samples, but none of the stations had this taxon in abundance similar to BIOREF streams.

Many dominant taxa found in BIOREF samples were also common in one or more of the Clear Creek samples. The only exceptions were the amphipod *Hyalella azteca* and the mayfly *Paraleptophlebia*. These were among the most abundant taxa found in BIOREF streams, but they were found in low abundance or were absent in Clear Creek samples. Most of the dominant taxa found in Clear Creek and BIOREF streams had BI values that were ≥ 5 . The only exceptions were the water penny *P. herricki* and the caddisfly *Chimarra*, which have BI values in the intolerant range (BI=2.5-4.9) and the mayfly *Paraleptophlebia*, which has a BI in the very intolerant range (BI<2.5).

Table 6
 Percent Dominant Macroinvertebrate Families and Taxa at the Clear Creek Sampling Stations, and the Ozark/Neosho EDU Biological Criteria Reference Samples, Fall 2016

Variable-Station	Biotic Index	Ozark/Neosho EDU Reference Streams	Clear Creek #1 Test Station	Clear Creek #2 Test Station	Clear Creek #3 Test Station
Sample Number			16037	16036	16035
Percent Dominant Families					
Psephenidae		16.7	4.9	3.9	4.6
Chironomidae		12.9	27.2	19.4	28.4
Heptageniidae		8.8	<0.1	0.2	0.3
Hyalellidae		8.2	--	2.5	2.1
Elmidae		7.5	44.3	19.4	14.6
Physidae		0.2	10.4	0.6	2.2
Caenidae		3.4	4.8	9.2	15.6
Hydropsychidae		5.3	2.0	15.4	14.5
Baetidae		4.7	<0.1	14.0	6.9
Percent Dominant Taxa					
<i>Psephenus herricki</i>	2.5	15.9	4.9	3.9	4.6
<i>Hyalella azteca</i>	7.9	8.2	--	2.5	2.1
<i>Cheumatopsyche</i>	6.6	4.8	2.0	15.4	14.5
<i>Paraleptophlebia</i>	1.2	4.6	--	--	--
<i>Baetis</i>	6.0	3.2	--	8.2	2.2
<i>Stenelmis</i>	5.4	3.1	44.0	19.4	14.6
<i>Dicrotendipes</i>	7.9	0.6	17.7	3.9	1.0
<i>Physella</i>	9.1	0.2	10.4	0.6	2.2
<i>Caenis latipennis</i>	7.6	3.1	4.8	9.2	15.5
<i>Chimarra</i>	2.8	0.5	0.2	9.1	3.9
<i>Polypedilum illinoense</i> grp.	9.2	0.1	3.1	2.1	10.9
<i>Fallceon</i>	6.0	--	--	5.8	4.7

Biocriteria reference stream data values are average percent ($n = 10$).

Values in bold type represent the five dominant macroinvertebrate taxa for each station.

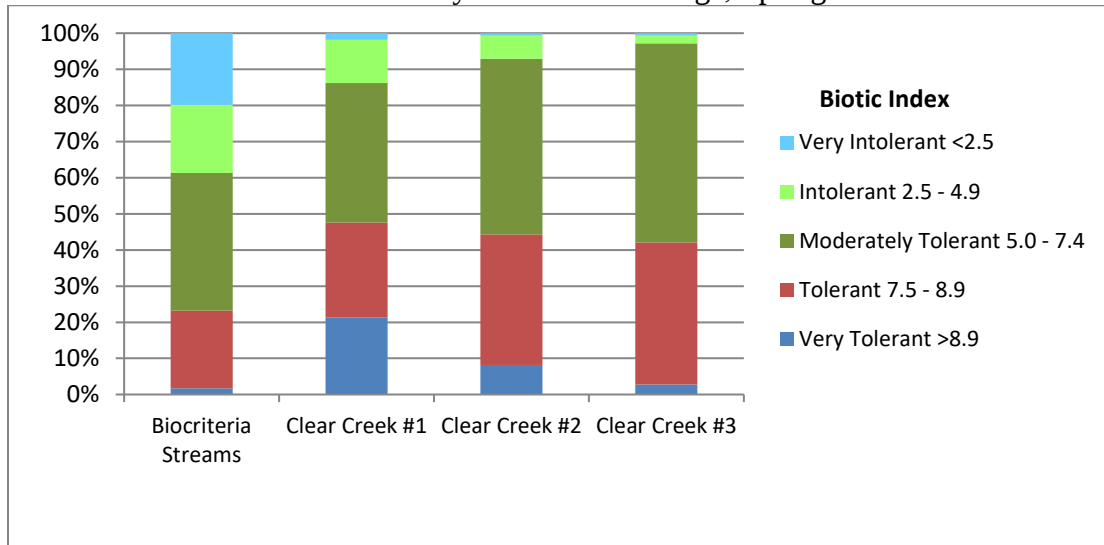
3.3.2.2 Spring 2017 Sampling Season

Percent Composition of Sensitive Taxa

Similar to the fall 2016 sampling season, taxa found in Clear Creek spring samples were more tolerant of organic pollution than BIOREF streams (Figure 5 and Table 7). Compared to the BIOREFs, Clear Creek samples had a higher percentage of taxa with BI values ≥ 5.0 . Taxa with BI values ≥ 5 made up an average of about 61 percent of BIOREF samples but about 86 to 97 percent of Clear Creek samples. Taxa with BI values ≤ 5.0 made up an average of about 39 percent of BIOREF samples, but values ranged from about 3 to 14 percent in Clear Creek. More Clear Creek taxa were in the moderately tolerant range (BI=5.0-7.4). Moderately tolerant BI

values ranged from slightly higher at Clear Creek #1 to much higher at the other two test stations compared to reference conditions. Clear Creek samples had a higher percentage of tolerant taxa (BI=7.5-8.9) and very tolerant taxa (BI>8.9) compared to BIOREF samples. Intolerant taxa (BI=2.5-4.9) and very intolerant taxa (BI<2.5) were much lower in Clear Creek than BIOREF samples. Very sensitive taxa were especially rare among Clear Creek samples, making up about 1-2 percent of samples. By comparison, very sensitive taxa make up an average of about 20 percent of BIOREF samples.

Figure 5
 Percent of Taxa by Biotic Index Range, Spring 2017



Percent Composition of Functional Feeding Groups (FFG)

Gatherer-collectors and shredders were the most abundant FFGs in Clear Creek samples (Figure 6 and Table 7). The percentage of Clear Creek gatherer-collectors was similar to or slightly lower than reference conditions. The percentage of shredders was higher at test stations #2 and #3 than BIOREF streams and much higher at test station #1. Percent scrapers ranged from much lower at test stations #3 to slightly lower at test station #1 compared to reference conditions. For percent filterers, values were much higher at the two upstream test stations but similar at test station #1 compared to reference streams. The percent scraper to filterer ratio was much lower at the two upstream test stations but was similar to reference streams at test station #1. Percent predator values were much lower among test stations than BIOREF streams.

Figure 6
 Percent of Taxa by Functional Feeding Group, Spring 2017

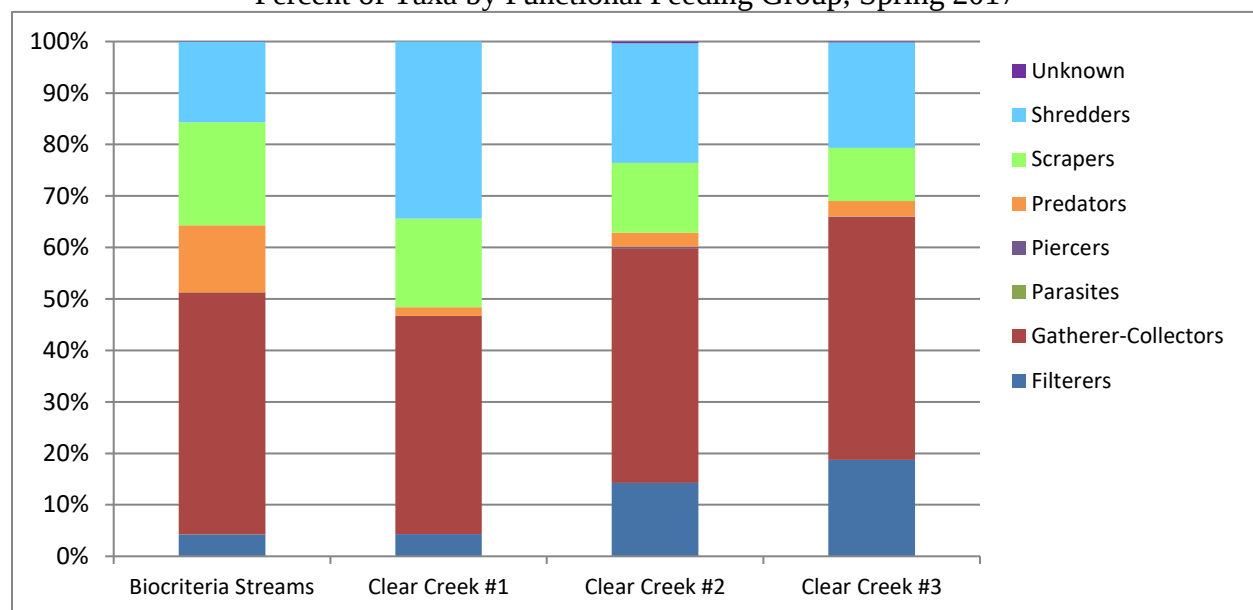


Table 7
 Biological Metric Values for Sensitive Taxa, Functional Feeding Groups (FFG), and EPTT Metrics at the Biological Criteria Reference Samples and Clear Creek Study Stations, Spring 2017

Variable-Station	Ozark/Neosho Biocriteria Reference Data	Clear Creek #1 Test Station	Clear Creek #2 Test Station	Clear Creek #3 Test Station
Sample Number		17003	17002	17001
Sensitive Taxa				
% Biotic Index >8.9	1.7	21.3	8.2	2.8
% Biotic Index 7.5-8.9	21.5	26.3	36.1	39.2
% Biotic Index 5.0-7.4	38.1	38.6	48.6	55.1
% Biotic Index 2.5-4.9	18.9	12.0	6.4	2.1
% Biotic Index <2.5	19.8	1.8	0.7	0.7
Functional Feeding Groups				
% Filterers	4.2	4.3	14.3	18.7
% Gatherer-Collectors	47.0	42.4	45.6	47.2
% Predators	13.0	1.7	2.9	3.0
% Scrapers	20.0	17.2	13.6	10.4
% Shredders	15.7	34.4	23.3	20.5
% Piercers	<0.1	--	0.3	0.1
% Unknown	<0.1	--	0.3	0.1
Scraper/Filterer Ratio	4.7	4.0	1.0	0.6
EPT Metrics				
% EPTT	39.7	13.5	25.8	20.8
% Ephemeroptera	27.5	11.1	15.4	10.1
% Plecoptera	7.4	--	--	--
% Trichoptera	4.8	2.4	10.3	10.7

Biocriteria stream data values are average percent ($n = 12$).

EPT Metrics

Percent EPTT, percent Ephemeroptera, and percent Plecoptera values were much lower in Clear Creek samples compared to reference conditions (Table 7). Although percent Trichoptera was also much lower than reference conditions at test station #1, this metric was much higher at the other two test stations. All of the EPT metrics except percent Ephemeroptera were much lower at test station #1 than the other test stations and the BIOREF streams. Percent Ephemeroptera ranged from about 10 percent to 15 percent among test stations; the average value among reference streams was about 28 percent. Plecoptera taxa made up an average of about 7 percent of BIOREF streams, but stoneflies were absent from all Clear Creek samples.

Macroinvertebrate Community Composition

Compared to reference conditions, chironomids were more abundant in Clear Creek samples, especially at test stations #2 and #3 (Table 8). Chironomid taxa *Cricotopus/Orthocladius* group, *Dicrotendipes*, and *Eukiefferiella* were more common in all or most of the Clear Creek samples than BIOREF streams. *P. illinoense* was more abundant at test station #1, and *P. flavum* and *Thienemanniella* were more abundant at test station #3 compared to reference conditions.

Some non-chironomid taxa also were common in one or more of the Clear Creek samples. The mayfly *C. latipennis* was much more common among all Clear Creek samples than BIOREF streams. The hydropsychid caddisfly *Cheumatopsyche* and planarians were more abundant at test stations #2 and #3 than reference conditions. The riffle beetle *Stenelmis* was more abundant at all Clear Creek stations compared to reference streams. Likewise, the snail *Physella* was more abundant than references in Clear Creek, but only at test stations #1 and #2.

Most of the dominant taxa found in BIOREF samples were not common in Clear Creek samples. The only exception was the chironomid *Cricotopus/Orthocladius* group, which was abundant among BIOREF streams and Clear Creek. Three of the dominant taxa found in BIOREF streams, the isopod *Lirceus* and mayflies *Leucrocuta* and *Paraleptophlebia*, were absent in Clear Creek samples. The chironomid *Thienemannimyia* group, the other dominant taxon found in BIOREF streams, was found in very low numbers in Clear Creek. The two mayfly taxa that were commonly found in BIOREF streams had BI values in the very intolerant range (BI<2.5), *Lirceus* has a BI value in the tolerant range (BI = 7.5-8.9), and *Thienemannimyia* group has a BI value in the moderately tolerant range (BI = 5.0-7.4). Most of the dominant taxa found in Clear Creek samples had BI values in the moderately tolerant or tolerant ranges. The only exceptions were *Eukiefferiella*, which has a BI value in the sensitive range (BI = 2.5-4.9) and *P. illinoense* group, which has a BI value in the very tolerant range (BI>8.9).

Table 8
 Percent Dominant Macroinvertebrate Families and Taxa at the Clear Creek Sampling Stations,
 and the Ozark/Neosho EDU Biological Criteria Reference Samples, Spring 2017

Variable-Station	Biotic Index	Ozark/Neosho EDU Reference Streams	Clear Creek #1 Test Station	Clear Creek #2 Test Station	Clear Creek #3 Test Station
Sample Number			17003	17002	17001
Percent Dominant Families					
Chironomidae		28.6	39.3	51.2	55.7
Asellidae		14.3	0.2	--	--
Heptageniidae		9.9	0.1	0.3	<0.1
Baetidae		6.1	<0.1	3.2	1.6
Leptophlebiidae		5.6	--	--	--
Caenidae		1.5	10.9	11.9	8.4
Physidae		0.1	7.5	6.2	1.2
Elmidae		3.7	5.4	5.5	7.5
Hydropsychidae		1.0	2.2	8.6	10.0
Planariidae		0.8	1.0	7.7	11.3
Percent Dominant Taxa					
<i>Lirceus</i>	7.7	13.1	--	--	--
<i>Cricotopus/Orthocladius</i> grp.	6.5	10.6	21.7	15.6	4.1
<i>Leucrocota</i>	0	3.9	--	--	--
<i>Paraleptophlebia</i>	1.2	3.6	--	--	--
<i>Thienemannimyia</i> grp.	6.0	3.4	--	0.1	0.2
<i>Dicrotendipes</i>	7.9	0.5	11.5	9.7	13.2
<i>Caenis latipennis</i>	7.6	1.4	10.9	11.9	8.4
<i>Polypedilum illinoense</i> grp.	9.2	0.1	10.5	1.1	0.9
<i>Eukiefferiella</i>	4.0	1.6	9.4	3.5	0.4
<i>Cheumatopsyche</i>	6.6	1.0	2.2	8.5	9.9
Planariidae	7.5	0.8	1.0	7.7	11.3
<i>Polypedilum flavum</i>	5.3	0.9	0.6	1.4	11.3
<i>Thienemanniella</i>	6.0	0.4	1.0	4.4	9.3

Biocriteria reference stream data values are average percent ($n = 12$)

Values in bold type represent the five dominant macroinvertebrate taxa for each station.

3.4 Physicochemical Water Data

Water samples and field measurements were collected during the fall 2016 and spring 2017 macroinvertebrate sampling periods (Table 9). Chloride and sulfate concentrations were higher than BIOREF streams but below WQS chronic criteria. DO was below the water quality criterion of 5 mg/L at two test stations during the fall 2016 sampling season. Nutrient concentrations were higher than U.S. EPA Nutrient Criteria recommended reference values for the Level III Ozark Highlands ecoregion (U.S. EPA 2000). Physicochemical results are arranged in the following sections to demonstrate trends of certain variables that may suggest a source of effects at the Clear Creek sampling stations. Results shown here are for stream discharge, conductivity, sulfate, DO, nitrate + nitrite-N, total nitrogen, total phosphorus, and turbidity by season.

3.4.1 Stream Discharge

Discharge values decreased from upstream to downstream during both sampling seasons, with highest values at test station #3 and the lowest values at test stations #1. During the fall 2016 sampling season, discharge ranged from 2.6 cfs at Clear Creek #3 to 1.2 cfs at Clear Creek #1

(Table 9). During the spring 2017 sampling season, discharge ranged from 4.0 cfs at Clear Creek #3 to 0.7 cfs at Clear Creek #1.

3.4.2 Conductivity

Clear Creek conductivity was higher than reference conditions during both sampling seasons (Table 9). In fall 2016 conductivity ranged from 1363 $\mu\text{mhos/cm}$ at test station #3 to 1230 $\mu\text{mhos/cm}$ at test station #1. During the spring 2017 sampling season, conductivity ranged from 1812 $\mu\text{mhos/cm}$ at test station #1 to 1688 $\mu\text{mhos/cm}$ at test station #3. Conductivity among BIOREF streams ranged from 288 to 308 $\mu\text{mhos/cm}$ ($n = 7$) in fall and from 242 to 316 $\mu\text{mhos/cm}$ ($n = 6$) in spring.

3.4.3 Chloride

Although chloride concentrations were higher in Clear Creek samples than reference conditions during both sampling seasons, they were below the Missouri WQS (MoDNR 2014b). In fall 2016 chloride ranged from 129 mg/L at test station #2 to 133 mg/L at test station #3 (Table 9). During the spring 2016 sampling season, chloride ranged from 170 mg/L at test stations #2 and #3 to 182 mg/L at test station #3. Among BIOREF streams, chloride ranged from <5.0 to 5.82 mg/L ($n = 7$) in fall and from <5.0 to 8.33 mg/L ($n = 6$) in spring.

3.4.4 Sulfate

Sulfate concentrations were higher in Clear Creek samples than reference conditions during both sampling seasons but were below the Missouri WQS (MODNR 2014b). In the fall 2016 sampling season, sulfate ranged from 221 mg/L at test station #1 to 288 mg/L at test station #3 (Table 9). In spring 2017 sulfate ranged from 322 mg/L at test station #3 to 349 mg/L at test station #1. Sulfate was not analyzed for water samples collected at BIOREF streams, but it was part of the analysis suite for candidate reference streams sampled during the 2013-2014 Cave Springs Branch biological assessment study (MoDNR 2014a). Sulfate at the candidate reference streams ranged from 3.5 to 8.43 mg/L ($n = 6$) in fall and from 6.43 to 7.2 mg/L ($n = 5$) in spring.

3.4.5 Dissolved Oxygen

DO was below the 5 mg/L Missouri water quality criterion at test stations #2 and #3 during the fall 2016 sampling season; however, DO values were above the criterion at all Clear Creek stations in spring 2017. In fall 2016, DO ranged from 4.42 mg/L at test station #3 to 5.67 mg/L at test station #1. During the spring 2017 sampling season, DO ranged from 11.42 mg/L at test station #3 to 12.84 mg/L at test station #3.

3.4.6 Nitrate + Nitrite-N

Nitrate + nitrite-N was much higher in Clear Creek samples (Table 9) during both sampling seasons compared to the U.S. EPA recommended reference value (0.24 mg/L) (U.S. EPA 2000). During the fall 2016 sampling season, nitrate + nitrite-N ranged from 22.8 mg/L at test station #3 to 25.7 mg/L at test station #1. In spring 2017 nitrate + nitrite-N ranged from 24.3 mg/L at test station #3 to 27.2 mg/L at test station #1.

Table 9
 Physicochemical Variables for Surface Water Samples at the Clear Creek Bioassessment Study
 Sampling Stations, Fall 2016 and Spring 2017

	Clear Creek #1	Clear Creek #2	Clear Creek #3
Fall 2016 Sampling Season			
Invertebrate Sample Number	16037	16036	16035
Physicochemical Sample Number	163790	163786	163784
Sample Date	09/21/2016	09/21/2016	09/21/2016
Sample Time	1200	1020	0820
Ammonia	0.03 ^a	0.05 ^a	0.08
Chloride	133	129	131
Sulfate	221	269	288
Total Recoverable Calcium	48.8	52.3	53.2
Total Recoverable Magnesium	10.8	11.4	11.2
Hardness as CaCO ₃	166	178	179
Dissolved Oxygen	5.67	4.90	4.42
Discharge (cfs)	1.2	2.1	2.6
pH (Units)	7.8	7.7	7.8
Conductivity (µmhos/cm)	1230	1306	1363
Temperature (°C)	24.0	24.9	24.4
Turbidity (NTU)	1.4	<1	<1
Total Suspended Solids	<5 ^b	<5 ^b	<5 ^b
Nitrate + Nitrite	25.7^c	23.7^c	22.8^c
Total Nitrogen	24.5^c	21.9^c	21.4^c
Total Phosphorus	8.44	8.87	9.91
Spring 2017 Sampling Season			
Invertebrate Sample Number	17003	17002	17001
Physicochemical Sample Number	171907	171906	171905
Sample Date	03/15/2017	03/15/2017	03/15/2017
Sample Time	1340	1235	1130
Ammonia	0.05 ^a	0.08	0.11
Chloride	182	170	170
Sulfate	349	336	322
Total Recoverable Calcium	59.3	56.8	60.8
Total Recoverable Magnesium	14.4	13.8	14.6
Hardness as CaCO ₃	207	199	212
Dissolved Oxygen	12.84	11.97	11.42
Discharge (cfs)	0.7	1.7	4.0
pH (Units)	8.4	8.3	8.2
Conductivity (µmhos/cm)	1812	1728	1688
Temperature (°C)	5.7	7.2	8.0
Turbidity (NTU)	2.1	1.6	1.1
Total Suspended Solids	<5 ^b	<5 ^b	<5 ^b
Nitrate + Nitrite	27.2^c	25.4^c	24.3^c
Total Nitrogen	28.2^c	28.4^c	27.4^c
Total Phosphorus	15.3^c	11.9^c	12.8^c

^a Estimated value, detected below Practical Quantitation Limit

^b Below detectable limits

^c Sample was diluted during analysis

Units mg/L unless otherwise noted. Values in bold exceed Missouri WQS or are elevated compared to U.S. EPA recommended reference condition values.

3.4.7 Total Nitrogen

Total nitrogen was much higher in Clear Creek samples (Table 9) during both sampling seasons compared to the U.S. EPA recommended reference value (0.29 mg/L) (U.S. EPA 2000). During the fall 2016 sampling season, total nitrogen ranged from 21.4 mg/L at test station #3 to 24.5 mg/L at test station #1. In spring 2017 total nitrogen ranged from 27.4 mg/L at test station #3 to 28.2 mg/L at test station #1.

3.4.8 Total Phosphorus

Total phosphorus was much higher in Clear Creek samples (Table 9) during both sampling seasons compared to the U.S. EPA recommended reference value (0.007 mg/L) (U.S. EPA 2000). During the fall 2016 sampling season, total phosphorus ranged from 8.44 mg/L at test station #1 to 9.91 mg/L at test station #3. Total phosphorus ranged from 11.9 mg/L at test station #2 to 15.3 mg/L at test station #1 in spring 2017.

3.4.9 Turbidity

Turbidity was below the U.S. EPA recommended reference value (1.43 NTU) (U.S. EPA 2000) at all test stations in fall 2016. In spring 2017, however, test stations #1 and #2 had higher turbidity readings than the recommended value. In the fall, turbidity ranged from <1 NTU at test stations #2 and #3 to 1.4 NTU at test station #1. Turbidity ranged from 1.1 NTU at test station #3 to 2.1 NTU at station #1 in spring 2017.

4.0 Historical Data Trends

4.1 Macroinvertebrate Biological Assessment

4.1.1 MSCI and Biological Metrics

MSCI scores from 1997 and 2000 samples were similar to the current study (2016-2017) at most stations (Table 10). All fall samples, regardless of sample year, had partially supporting individual metrics scores for TR, BI, and SDI and non-supporting scores for EPTT, which resulted in partially supporting MSCI scores of 10.

There were scoring differences among time periods, however, in the Clear Creek #2 and #3 spring samples. Whereas both stations had non-supporting MSCI scores of 6 or 8 in 1997 and 2000, they had partially supporting MSCI scores of 10 during the spring 2017 sampling season. Non-supporting MSCI scores in the 1997 and 2000 spring samples resulted from non-supporting TR and EPTT individual metric values. In addition to TR and EPTT, the station #3 spring 2000 sample also had a non-supporting BI value. Although EPTT was in the non-supporting range and SDI was in the partially supporting range during the spring sampling season during all sampling periods, these two metrics had higher values at test stations #2 and #3 in 2017 compared to 1997 and 2000. Test station #2 and #3 TR values also were higher in spring 2017 compared to past studies, which resulted in this individual metric increasing from a non-supporting to a partially supporting score.

Table 10
 Riffle/Pool Ozark/Neosho EDU Perennial/Wadeable Biological Criteria, Biological
 Support Categories, and Macroinvertebrate Stream Condition Index (MSCI) Scores at the
 Clear Creek Sampling Stations

Station	Sample Year	Sample No.	TR	EPTT	BI	SDI	MSCI	Support
Fall Sampling Season								
Clear Creek #1	2000	0010133	53 (3)	8 (1)	7.1 (3)	2.76 (3)	10	P
	2016	16037	42 (3)	6 (1)	6.6 (3)	2.01 (3)	10	P
Clear Creek #2	1997	970238	47 (3)	6 (1)	6.9 (3)	2.71 (3)	10	P
	2016	16036	43 (3)	9 (1)	6.2 (3)	2.72 (3)	10	P
Clear Creek #3	1997	970239	45 (3)	6 (1)	7.3 (3)	2.97 (3)	10	P
	2000	0010134	43 (3)	6 (1)	7.1 (3)	2.85 (3)	10	P
	2016	16035	39 (3)	9 (1)	6.6 (3)	2.77 (3)	10	P
Metric Score=5		If	>77	>24	<5.5	>2.97	20-16	Full
Metric Score=3		If	77-39	24-12	5.5-7.7	2.97-1.49	14-10	Partial
Metric Score=1		If	<39	<12	>7.7	<1.49	8-4	Non
Spring Sampling Season								
Clear Creek #1	2000	0010104	41 (3)	5 (1)	7.3 (3)	2.73 (3)	10	P
	2017	17003	53 (3)	7 (1)	6.9 (3)	2.70 (3)	10	P
Clear Creek #2	1997	970208	33 (1)	3 (1)	6.8 (3)	1.80 (3)	8	N
	2017	17002	45 (3)	9 (1)	6.8 (3)	2.96 (3)	10	P
Clear Creek #3	1997	970209	28 (1)	2 (1)	6.9 (3)	1.55 (3)	8	N
	2000	0010105	30 (1)	3 (1)	8.0 (1)	1.62 (3)	6	N
	2017	17001	48 (3)	9 (1)	6.7 (3)	2.78 (3)	10	P
Metric Score=5		If	>72	>27	<5.3	>3.01	20-16	Full
Metric Score=3		If	72-36	27-13	5.3-7.7	3.01-1.51	14-10	Partial
Metric Score=1		If	<36	<13	>7.7	<1.51	8-4	Non

MSCI Scoring Table (in light gray) developed from Ozark/Neosho EDU BIOREF samples (n=10 for fall samples and N=12 for spring samples); TR=taxa richness; EPTT=Ephemeroptera, Plecoptera, Trichoptera Taxa; BI=Biotic Index; SDI=Shannon Diversity Index

4.1.2 Macroinvertebrate Community Composition

Fall Sampling Season

Percent EPT was much lower in the fall 1997 samples than 2000 and 2016 at test stations #2 and #3 (Table 11). Although percent EPT was similar between 2000 and 2016 at test station #3, this metric was much higher in 2000 at test station #1.

Many of the dominant taxa collected in fall were common in all samples, but there were large differences in abundance of some taxa among sample years (Table 11). Chironomids were abundant in all samples, but they were much more abundant in the 1997 samples. A large portion of the higher chironomid abundance in 1997 was due to *Tanytarsus* and *Thienemannimyia* group. The mayfly *C. latipennis* was much more abundant in 2000 than most samples from other years. Coenagrionid damselflies (primarily *Argia* and *Enallagma*) were much more abundant in 1997 and 2000 than 2016. Except at test station #1, baetid mayflies (primarily *Baetis* and *Fallceon*) were more numerous in 2016 than 1997 and 2000. The elmid riffle beetle *Stenelmis*, the water penny *P. herricki*, and the hydropsychid caddisfly *Cheumatopsyche* were more abundant in 2016 than other sample years. The hydrophilid beetle *Berosus* was more abundant in 1997 and 2000 than in 2016.

Spring Sampling Season

Percent EPT was much lower in spring 1997 than 2017 at test station #2. At test station #3, percent EPT was considerably lower in both 1997 and 2000 compared to 2017 (Table 12). At test station #1, however, percent EPT was slightly higher in 2000 than 2017.

Similar to fall, many dominant taxa were common among all spring samples, but there were some differences in abundance between sample years (Table 12). Chironomids were the most abundant taxa group in all samples, but they were much more abundant in the 1997 samples and the 2000 Clear Creek #3 sample. *Cricotopus/Orthocladius* group was common among all samples, but it was more abundant (>50 percent of sample) in 1997 samples. The tolerant chironomid *Cricotopus bicinctus* was more abundant in the 2000 samples and made up almost 60 percent of the Clear Creek #3 sample. The chironomid *Dicrotendipes* was much more common in Clear Creek in 2017 and at Clear Creek #3 in 1997 than other samples. *P. illinoense* group was much more common at Clear Creek #1 in 2017 and at Clear Creek #3 in 1997 and 2000. *Eukiefferiella* was much more common at Clear Creek #1 and #2 in 2017 than the rest of the samples. Two chironomids in the subfamily Tanypodinae, *Ablabesmyia* and *Thienemannimyia* group, were much more common in 1997 samples and at Clear Creek #3 in 2000. *Thienemanniella* were abundant at Clear Creek #3 in 2000 and 2017; *P. flavum* also was common at Clear Creek #3, but only in 2017.

Non-chironomid taxa also were common in some samples. The mayfly *C. latipennis* and the riffle beetle *Stenelmis* were common in 2017 samples and at Clear Creek #1 in 2000. The hydropsychid caddisfly *Cheumatopsyche* and Planariidae were much more common at Clear Creek #2 and #3 in 2017 than in the other samples. The damselfly *Argia* and the hydrophilid beetle *Berosus* were more abundant at Clear Creek #1 in 2000 and at Clear Creek #2 in 1997 than in the other samples.

Table 11

Percent EPT, Dominant Macroinvertebrate Families and Macroinvertebrate Taxa at the Clear Creek Stations, Fall Samples

Variable-Station	Biotic Index	Clear Creek #1		Clear Creek #2		Clear Creek #3		
Sample Number		0010133	16037	970238	16036	970239	0010134	16035
Sample Year		2000	2016	1997	2016	1997	2000	2016
EPT Metrics								
% EPT		34.1	7.3	13.8	48.9	13.0	37.0	43.2
% Ephemeroptera		31.8	2.1	6.4	24.3	5.8	24.4	24.7
% Plecoptera		--	--	--	--	--	--	--
% Trichoptera		2.3	2.2	7.4	24.6	7.2	12.6	18.5
Percent Dominant Families								
Chironomidae		32.0	27.2	58.9	19.4	52.0	42.0	28.4
Caenidae		24.2	4.8	2.0	9.2	0.8	20.0	15.6
Coenagrionidae		14.1	--	7.1	2.9	6.0	5.5	1.6
Baetidae		7.7	<0.1	4.4	14.0	5.0	4.3	6.9
Elmidae		7.4	44.3	13.5	19.4	6.6	5.5	14.6
Physidae		0.1	10.4	0.4	0.6	0.6	0.7	2.2
Psephenidae		3.0	4.9	0.4	3.9	<0.1	--	4.6
Hydropsychidae		1.7	2.0	6.1	15.4	6.2	11.7	14.5
Hydrophilidae		1.3	0.2	3.6	--	11.9	3.8	--
Percent Dominant Taxa								
<i>Caenis latipennis</i>	7.6	24.2	4.8	2.0	9.2	0.8	20.0	15.5
<i>Argia</i>	8.7	10.6	--	1.5	2.3	2.5	2.8	1.2
<i>Rheotanytarsus</i>	6.4	9.7	--	--	0.1	--	--	4.0
<i>Stenelmis</i>	5.4	7.4	44.0	13.5	19.4	6.6	5.5	14.6
<i>Tanytarsus</i>	6.7	6.1	0.3	24.4	5.6	16.8	13.6	2.4
<i>Dicrotendipes</i>	7.9	2.7	17.7	2.6	3.9	6.2	0.9	1.0
<i>Physella</i>	9.1	0.1	10.4	0.4	0.6	0.6	0.7	2.2
<i>Psephenus herricki</i>	2.5	3.0	4.9	0.4	3.9	0.1	--	4.6
<i>Paratanytarsus</i>	7.7	1.1	--	10.9	0.3	1.4	2.1	0.1
<i>Thienemannimyia</i> grp.	6.0	0.5	--	7.7	0.1	8.5	0.9	0.3
<i>Cheumatopsyche</i>	6.6	1.5	2.0	6.1	15.4	6.1	11.7	14.5
<i>Chimarra</i>	2.8	--	0.2	--	9.1	--	--	3.9
<i>Baetis</i>	6.0	2.0	--	4.4	8.2	5.0	2.3	2.2
<i>Berosus</i>	8.6	1.3	--	3.6	--	11.9	3.8	--
<i>Thienemaniella</i>	6.0	0.8	--	0.5	--	1.4	6.7	0.1
<i>Nanocladius</i>	7.2	0.2	--	0.5	--	0.4	5.5	--
<i>Polypedilum illinoense</i> grp.	9.2	0.1	3.1	0.7	2.1	2.3	2.2	10.9
<i>Fallceon</i>	6.0	5.7	--	--	5.8	--	2.0	4.7

Table 12

Percent EPT, Dominant Macroinvertebrate Families and Macroinvertebrate Taxa at the Clear Creek Stations, Spring Samples

Variable-Station	Biotic Index	Clear Creek #1		Clear Creek #2		Clear Creek #3		
Sample Number		0010104	17003	970208	17002	970209	0010105	17001
Sample Year		2000	2017	1997	2017	1997	2000	2017
EPT Metrics								
% EPT		19.0	13.5	2.4	25.7	0.8	1.6	20.8
% Ephemeroptera		17.7	11.1	1.7	15.4	0.7	0.1	10.1
% Plecoptera		--	--	--	--	--	--	--
% Trichoptera		1.3	2.4	0.7	10.3	0.1	1.5	10.7
Percent Dominant Families								
Chironomidae		53.1	69.3	81.4	51.2	89.5	92.0	55.7
Caenidae		17.7	10.9	1.7	11.9	0.7	0.1	8.4
Elmidae		9.4	5.4	2.1	5.5	0.3	0.3	7.5
Coenagrionidae		7.3	0.1	5.1	0.1	2.7	0.1	1.0
Planariidae		4.5	1.0	--	7.7	--	0.1	11.3
Physidae		--	7.5	0.9	6.2	2.4	2.7	1.2
Hydropsychidae		0.6	2.2	0.4	8.6	--	1.3	10.0
Hydrophilidae		2.4	--	3.5	--	0.8	0.8	--
Tubificidae		--	--	1.7	0.1	2.2	0.4	0.1
Calopterygidae		--	--	0.4	--	0.1	1.3	0.1
Percent Dominant Taxa								
<i>Caenis latipennis</i>	7.6	17.7	10.9	1.7	11.9	0.7	0.1	8.4
<i>Cricotopus/Orthocladius</i> grp.	6.5	16.4	21.7	56.3	15.6	60.1	3.8	4.1
<i>Cricotopus bicinctus</i>	8.7	13.0	0.4	--	0.8	--	57.6	3.1
<i>Stenelmis</i>	5.4	9.4	5.4	2.1	5.5	0.3	0.3	7.5
<i>Argia</i>	8.7	4.8	--	3.3	0.9	1.0	0.1	1.0
<i>Dicrotendipes</i>	7.9	3.0	11.5	1.2	9.7	10.0	0.5	13.2
<i>Polypedilum illinoense</i> grp.	9.2	2.5	10.5	2.4	1.1	4.3	7.12	0.9
<i>Eukiefferiella</i>	4.0	--	9.4	--	3.5	--	--	0.4
<i>Thienemannimyia</i> grp.	6.0	3.0	0.2	14.6	0.1	10.7	4.7	0.2
<i>Berosus</i>	8.6	2.4	--	3.5	--	0.8	0.8	--
<i>Ablabesmyia</i>	6.4	2.5	0.9	3.3	1.5	3.7	5.5	1.1
<i>Cheumatopsyche</i>	6.6	0.6	2.2	0.4	8.5	--	1.3	9.9
<i>Planariidae</i>	7.5	4.5	1.1	--	7.7	--	0.1	11.3
<i>Thienemanniella</i>	6.0	1.3	1.0	--	4.4	0.1	12.3	9.3
<i>Polypedilum flavum</i>	5.3	0.3	0.6	--	1.4	--	--	11.3

4.2 Physicochemical Data

A comparison of water quality data from samples collected in 1997 and 2000 to samples collected during the current study showed nutrient concentrations during both sampling periods to be higher than U.S. EPA recommended values for the Level III Ozark Highlands ecoregion (Tables 13 and 14). Water quality conditions could not be assessed for most the 1997 macroinvertebrate samples because water samples were collected only at Clear Creek #2 in fall 1997. In comparing the three fall sampling seasons (1997, 2000, and 2016), nitrate + nitrite-N was much higher in the 2016 samples and total phosphorus was much higher in the 2000 samples. The 1997 Clear Creek #2 nitrate + nitrite-N concentration was lower than all other samples, and total phosphorus was between levels found in 2000 and 2016. DO concentrations were lower in fall 2016 compared to previous fall samples, and two values were below the 5 mg/L minimum required by the WQS.

In comparing spring samples (2000 and 2017), nitrate + nitrite-N was much higher in 2017. Total phosphorus values, however, were similar between years. Similar to the fall sampling season, spring DO concentrations also were lower in the current study compared to 2000. It should be noted, however, that the 2000 DO concentrations were supersaturated (roughly 190 and 203 percent saturation at test stations #1 and #3, respectively). Although spring 2017 DO concentrations were lower than 2000, they were at (test station #3) or slightly above (test stations #1 and #2) saturation.

Water quality data from other Clear Creek studies have shown similar results for nutrients and DO (Table 15). Most of the additional data were collected for waste load allocation (WLA) studies in August 2000, 2002, and 2016. Data loggers were deployed during 2002 and 2016 WLA studies near Clear Creek #2 and #3. At Clear Creek #2, DO ranged from 3.99 to 7.77 mg/L ($n = 385$) in 2002, and 39.22 percent of values were below the 5 mg/L minimum WQS (MoDNR 2002). At station #3, all DO values were above 5 mg/L, ranging from 5.4 to 9.42 mg/L ($n = 384$) in 2002. In 2016 Clear Creek #3 DO ranged from 4.50 to 7.77 mg/L ($n = 186$), and 37.1 percent of values were below 5 mg/L. No data loggers were deployed at Clear Creek # 2 during 2016 WLA study (MoDNR 2016g). All of the DO readings in 2016 and most of the readings in 2002 that were below the WQS occurred in the early morning hours starting around midnight and lasting until about 0800-0900 h.

Table 13
 Physicochemical Variables from Water Samples collected at the Clear Creek Bioassessment
 Study Sampling Stations, Fall Sampling Season

	Clear Creek #1		Clear Creek #2		Clear Creek #3	
Sample Number	0007135	163790	970301	163786	0007136	163784
Sample Year	2000	2016	1997	2016	2000	2016
Sample Date	10/04/2000	09/21/2016	09/15/1997	09/21/2016	09/24/2000	09/21/2016
Sample Time	1215	1200	1645	1020	1425	0820
Ammonia	<0.05 ^a	<0.03 ^b	0.06	<0.05 ^b	<0.05 ^a	0.08
Chloride	210	133	212	129	205	131
Sulfate	--	221	--	269	--	288
Total Recoverable Calcium	--	48.8	--	52.3	--	53.2
Total Recoverable Magnesium	--	10.8	--	11.4	--	11.2
Hardness as CaCO ₃	--	166	180	178	--	179
Dissolved Oxygen	6.8	5.67	7.2	4.90	8.6	4.42
Discharge (cfs)	3.8	1.2	3.4	2.1	4.1	2.6
pH (Units)	7.9	7.8	--	7.7	8.0	7.8
Conductivity (µmhos/cm)	1600	1230	2140	1306	1720	1363
Temperature (°C)	21.0	24.0	28.0	24.9	23.0	24.4
Turbidity (NTU)	1.1	1.4	--	<1	4.5	<1
Total Suspended Solids	--	<5 ^a	--	<5 ^a	--	<5 ^a
Nitrate + Nitrite-N	15.60	25.7^c	12.1	23.7^c	17.2	22.8^c
TKN	<1.0 ^a	--	--	--	<1.0 ^a	--
Total Nitrogen	--	24.5^c	--	21.9^c	--	21.4^c
Total Phosphorus	20.9	8.44	13.4	8.87	23.0	9.91^c

^aBelow detectable limits

^bEstimated value, detected below PQL

^cSample was diluted during analysis

Units mg/L unless otherwise noted. Values in bold are elevated compared to Missouri WQS or U.S. EPA recommended reference condition values.

Table 14
 Physicochemical Variables from Water Samples collected at the Clear Creek Bioassessment
 Study Sampling Stations, Spring Sampling Season

	Clear Creek #1		Clear Creek #2	Clear Creek #3	
Sample Number	0007049	171907	171906	0001036	171905
Sample Year	2000	2017	2017	2000	2017
Sample Date	03/15/2000	03/15/2017	03/15/2017	03/15/2000	03/15/2017
Sample Time	1155	1340	1235	1455	1130
Ammonia	<0.1 ^a	<0.05 ^b	0.08	<0.1 ^a	0.11
Chloride	116	182	170	129	170
Sulfate	--	349	336	--	322
Total Recoverable Calcium	--	59.3	56.8	--	60.8
Total Recoverable Magnesium	--	14.4	13.8	--	14.6
Hardness as CaCO ₃	--	207	199	--	212
Dissolved Oxygen	17.5	12.84	11.97	18.0	11.42
Discharge (cfs)	3.9	0.7	1.7	4.2	4.0
pH (Units)	8.0	8.4	8.3	9.1	8.2
Conductivity (µmhos/cm)	1015	1812	1728	1200	1688
Temperature (°C)	14.0	5.7	7.2	19.0	8.0
Turbidity (NTU)	2.03	2.1	1.6	2.48	1.1
Total Suspended Solids	--	<5 ^a	<5 ^a	--	<5 ^a
Nitrate + Nitrite-N	11.7	27.2^c	25.4^c	15.7	24.3^c
TKN	<1.0 ^a	--	--	<2.0 ^a	--
Total Nitrogen	--	28.2^c	28.4^c	--	27.4^c
Total Phosphorus	12.8	15.3	11.9	10.1	12.8^c

^aBelow detectable limits

^bEstimated value, detected below PQL

^cSample was diluted during analysis

Units mg/L unless otherwise noted. Values in bold are elevated compared to Missouri WQS or U.S. EPA recommended reference condition values.

Table 15
 Historic Water Quality (Range of Values) from other studies for Nutrients and Dissolved
 Oxygen from Clear Creek samples collected from 1999 to 2018 (MoCWIS Database)

	Clear Creek @ Pierce City Park	Clear Creek #1	Clear Creek #2	Clear Creek #3
Sample Period	10/17/2017 to 04/05/2018	08/02/2000 to 08/10/2017	07/01/1999 to 08/03/2016	07/01/1999 to 08/03/2016
Number of Samples	4	5	12	16
Nitrate + Nitrite-N (mg/L)	7.64-19.5	11.9-16.4	11.9-29.2	11.4-29.5
Total Nitrogen (mg/L)	7.65-20.5	12.5-16.9	12.9-27.0	11.5-28.5
Total Phosphorus (mg/L)	2.96-19.63	4.5-8.6	9.58-17.8	9.91-18.6
Dissolved Oxygen (mg/L)	--	4.5-8.6	4.1-7.1	3.7-10.5

5.0 Discussion

The discussion describes possible effects of stream habitat and physicochemical conditions on the biological metric scores and the macroinvertebrate community composition.

5.1 Hydrology and Land Cover

Most of the land cover in the Clear Creek watershed was made up of grassland, but there were also notable percentages in the urban land cover classes. These urban land use classes included impervious surface, high intensity urban, and low intensity urban, the majority of which was from the city of Monett. The percentage of impervious surface in the watershed may have altered the hydrology of Clear Creek, an example being increased runoff, which has been shown in other studies (e.g. Lazaro 1990; Paul and Meyer 2001). The percentage of forest in the Clear Creek watershed was much lower than the Ozark/Neosho EDU overall and Jones Creek, a candidate reference stream.

A study comparing three streams with distinctly different land cover in the Piedmont region of North Carolina found differences in the macroinvertebrate community (Lenat and Crawford 1994). The study found that a stream located in a forested watershed had a much more sensitive macroinvertebrate community with a much higher abundance and diversity of EPTT compared to a stream located in an agricultural watershed and a stream located in an urban watershed. By contrast, the agricultural stream had a much higher abundance of dipteran taxa, especially chironomids, and the urban stream had a higher abundance of oligochaete worms. The relatively high urban and grassland land cover percentage in the Clear Creek watershed, in combination with the WWTF effluent, likely led to a macroinvertebrate community composition made up primarily of moderately tolerant to very tolerant taxa.

The geology of the watershed may also affect the hydrology of Clear Creek. The upper reach of Clear Creek, extending to about 0.4 miles downstream of station #3, is classified as a losing stream. Although the losing reach, as classified in the WQS (MoDNR 2014b), does not extend downstream to include stations #1 and #2, the discharge data suggest that this section of Clear Creek may also be losing. Discharge decreased in a downstream direction in both sample seasons.

5.2 Stream Habitat

Stream habitat assessments conducted during the fall 2016 sampling season suggest that the Clear Creek stations should be comparable to reference conditions in their ability to support a similar quality macroinvertebrate community. Although the overall habitat scores were similar to reference conditions, a few metrics scored in the suboptimal or poor category. Sediment deposition values were in the suboptimal range at test stations #1 and #3. Vegetative protection was either in suboptimal or poor range at all Clear Creek stations. Right bank condition at test station #1 and riparian zone width for both banks at test station #2 had scores in the poor range. Lemly (1982) found that increased sediment deposition, suboptimal riffle quality, and suboptimal riparian zone width can have an effect on the macroinvertebrate community composition. Although vegetative protection was generally poor at all stations, and riparian zone width was poor at test station #2, overall stream habitat scores were good and likely did not

affect the MSCI scores as much as other factors such as land cover and nutrient enrichment from point and non-point sources.

5.3 MSCI and Biological Metrics

All Clear Creek macroinvertebrate samples during both sampling seasons had partially supporting MSCI scores of 10 using Ozark/Neosho EDU biological criteria. All test stations had partially supporting TR, BI, and SDI metric values and non-supporting EPTT values. Relative to biological criteria thresholds, EPTT values were very low in Clear Creek, ranging from 6 to 9 in fall samples and 7 to 9 in spring samples.

A comparison of biological metrics in earlier studies versus the current study showed that most biological metric values were similar and in the same support category. Exceptions included TR at Clear Creek #2 and #3 in 1997 and TR and BI at Clear Creek #3 in 2000. Metric values in those samples were in the non-supporting range. Although MSCI scores and biological metric values for this study are higher than past studies, the macroinvertebrate community attained only the lowest partially supporting MSCI scores.

5.4 Macroinvertebrate Community Composition

The Clear Creek macroinvertebrate community was generally made up of more tolerant taxa than reference streams based on comparing the results of percent sensitive taxa, FFG percent scrapers, scraper/filterer ratio, and the overall macroinvertebrate community composition. The only exception was the fall 2016 Clear Creek #1 sample, which had much higher values for percent scrapers and scraper/filterer ratio than the other test stations and reference conditions. Percent scrapers and scraper/filterer ratio were lower and percent filterers were higher at the two upstream stations during both sampling seasons compared to reference conditions. Percent scrapers and scraper/filterer ratio are expected to decline and filterers are expected to increase as pollution or disturbance increases (Barbour et al. 1999).

Clear Creek samples were primarily made up of moderately tolerant (BI = 5.0-7.4) or tolerant taxa (BI = 7.5-8.9) taxa. Stoneflies were absent at all stations during both seasons; therefore, mayflies and caddisflies were the only taxa groups contributing to EPTT metrics. The percentage of mayflies and caddisflies making up fall 2016 samples was higher than reference conditions at Clear Creek stations #2 and #3 but much lower at station #1. In spring 2017, however, these metrics were much lower than reference conditions at all stations. Most of the higher abundance at the two upstream stations during the fall 2016 sampling season was from the hydropsychid caddisfly *Cheumatopsyche* at both sampling stations, *C. latipennis* and *Baetis* at test station #2, and *C. latipennis* and *Fallceon* at test station #3. Chironomidae was the most abundant family during both sampling seasons, and chironomids were more abundant during the spring 2017 sampling season. Most of the abundant chironomid taxa found in samples had BI values in the moderately tolerant to the very tolerant range. The only exception was *Eukiefferiella* (BI = 4.0), which was abundant at Clear Creek #1 during the spring 2017 sampling season. These results suggest that the macroinvertebrate community in Clear Creek was likely affected by water quality conditions resulting from a combination of land cover and the effluent from the Monett WWTF.

5.5 Physicochemical Effects

5.5.1 Nutrients

Surface water sample analyses from the current study showed that nitrate + nitrite-N, total nitrogen, and total phosphorus concentrations were much higher than U.S. EPA recommended reference values (U.S. EPA 2000). Each of these nutrients required dilution in one (total phosphorus) or both (total nitrogen and nitrate + nitrite-N) seasons during laboratory analysis. Previous studies also showed that Clear Creek nutrient levels were much higher than recommended reference conditions. MSCI scores, biological metrics, and the high abundance of moderately tolerant or tolerant taxa in Clear Creek indicate that nutrient concentrations are having an effect on the macroinvertebrate community. Studies of streams in the Midwest (Wang et al. 2007, Evans-White et al. 2009) calculated the concentrations at which nutrients affect macroinvertebrate communities. Wang et al. (2007) calculated that total nitrogen and total phosphorus affected TR at 0.86 mg/L and 0.04 mg/L, respectively. Wang et al. (2007) also found that Hilsenhoff BI values were affected by total nitrogen at 0.61 mg/L, and total phosphorus started having effects at 0.09 mg/L. Threshold values for TR from the Evans-White et al. (2009) study was 1.04 mg/L for total nitrogen and 0.05 mg/L for total phosphorus. These threshold values are higher than the U.S. EPA recommended reference values, but they are much lower than Clear Creek samples.

Other studies have found that nutrient enrichment can lead to secondary effects on macroinvertebrates, such as excessive algae growth, increases in suspended fine particulate organic matter and sediment retention (Graham 1990), and subsequent declines in interstitial space (Broekhuizen et al. 2001) and food quality (Evans-White et al. 2009). Macroinvertebrate communities downstream of WWTF outfalls have exhibited declines in EPTT (Dyer and Wang 2002), increases in hydropsychid caddisflies (Suckling 1982), increases in the nutrient-tolerant chironomids *Dicrotendipes* and *Cricotopus/Orthocladius* group (Jacobsen 2008), and decreases in percent scrapers and scraper/filterer ratio (Poulton et al. 2015). Many of these trends noted occurred in some or all of the Clear Creek samples. At the two upstream stations, EPTT was lower during the spring 2017 sampling season and percent Hydropsychidae Trichoptera was higher during both sampling seasons compared to reference conditions. In spring 2017, *Cricotopus/Orthocladius* and *Dicrotendipes* were higher in abundance at test stations #1 and #2, percent scrapers and scraper/filterer ratio were lower at test stations #2 and #3 during both seasons, and all samples had higher biotic index values than reference conditions (Tables 4-8).

5.5.2 Dissolved Oxygen

DO was below the WQS of 5 mg/L at test station #2 and #3 during the fall 2016 sampling season, and data loggers deployed during a WLA study in August 2016 recorded DO below WQS 37.1 percent of the time at test station #3. In an August 2002 WLA study, data loggers found that DO was below WQS 39.22 percent of time at test station #2. BI, a measure of macroinvertebrate tolerance to organic pollution (higher BI values indicate higher tolerance), is likely related to DO levels. This metric value was higher at all Clear Creek test stations than the fully supporting threshold for that metric during both sampling seasons. Many macroinvertebrate taxa that have high BI values, such as the chironomids may also be tolerant of low DO levels. For example, some *Dicrotendipes* species, which were common in some Clear Creek samples, are tolerant of low DO. One such species, *Dicrotendipes neomodestus*, is common to rivers and

streams and has been found to be tolerant of nutrient enrichment and organic wastes (Epler 2001; Simpson and Bode 1980). Simpson and Bode (1980) found that *Dicrotendipes nervosus* is tolerant of high chlorides, high biochemical oxygen demand, and low DO levels. Another species, *Dicrotendipes simpsoni*, is tolerant of high nutrient levels and low DO (Epler 2001). Another chironomid common in many of the Clear Creek samples, *P. illinoense* group, is commonly found in conditions with high organic loading and low DO levels (Epler 2001).

5.6 Historical Data Trends

MSCI scores and biological metrics collected from earlier studies were similar for most samples compared to the current study. The only exceptions were Clear Creek #2 and #3 spring samples, which had non-supporting MSCI scores of 6 or 8 in 1997 and 2000; all other samples had partially supporting MSCI scores of 10. (Table 10). Many of the dominant taxa were common in all samples collected, but there were some differences in abundance among sample years. For example, chironomids were more abundant during both sampling seasons in 1997, and the elm mid riffle beetle *Stenelmis*, the water penny *P. herricki*, and the hydropsychid caddisfly *Cheumatopsyche* were more abundant in fall 2016 samples (Tables 11 and 12). Differences in the macroinvertebrate community composition likely led to some of the differences in the biological metric values among sample years. During the fall 2016 season, BI was consistently lower at all test stations, and TR was much lower at test station #1. Results from the spring 1997 and 2000 sampling seasons showed that TR was much lower at all test stations, and EPTT and SDI were much lower at test stations #2 and #3. Results for the biological metrics and MSCI scores show that the macroinvertebrate community was in poor condition during all years sampled, but spring 1997 and 2000 biological metrics were lowest at test stations #2 and #3.

Water quality results showed that nutrients were elevated in previous samples, and they continue to be elevated based on samples collected for this study. Nutrients were much higher than U.S. EPA recommended reference values (Tables 13-15). Nitrate + nitrite-N was much higher in the fall 2016 and spring 2017 samples than samples collected in 1997 and 2000. Total phosphorus concentrations were much lower in the fall 2016 samples compared 1997 and 2000; however, spring values were similar among sample years. Although some differences existed among sample years, all nitrate + nitrite-N and total phosphorus values were very high and likely contribute to eutrophic conditions in Clear Creek.

Nutrient concentrations, mainly phosphorus and nitrogen species, are likely responsible for the DO patterns described in this report. In eutrophic systems such as Clear Creek, DO concentrations can exhibit wide fluctuations during the day corresponding to diel patterns of photosynthesis and respiration of algae and other plants (Wetzel 1983). Although 2016 WLA data logger readings did not show extreme low and high DO concentrations, the lowest concentrations were below WQS, and some of the afternoon high readings were above saturation. Likewise, DO readings were at or above saturation at each station when grab samples were collected in spring 2017. These observations are consistent with high nutrient concentrations resulting in increased algal production.

Clear Creek has a history of low DO observations. Water quality surveys in 1978 and 1985 found that Clear Creek had very low DO levels (2-3 mg/L range) downstream of the Monett

WWTF (MoDNR 1999). Data loggers deployed during WLA studies in 2002 and 2016 recorded DO levels below the WQS of 5 mg/L at test stations #2 and #3 (MoDNR 2002b and 2016g). During the summer of 2002, DO levels at Clear Creek #2 (range of 3.99 to 7.77 mg/L) were below the WQS in 39 percent of the samples and about 37 percent of samples at test station #3 in 2016 (range of 4.50 to 7.77 mg/L). During the fall 2016 macroinvertebrate sample season, DO measured during the morning hours at test stations #2 and #3 was also below the WQS. Test station #1, which was sampled at noon, had a DO concentration that was slightly above WQS. Comparing more recent samples collected in 2002 and 2016 to historical data indicate that present DO levels are not as low as those collected in 1978 and 1985. Even with improved DO levels compared to historical conditions, some taxa like *Dicrotendipes*, which are known to be tolerant of low DO levels, were common in the current study.

6.0 Conclusions

Clear Creek MSCI scores indicate that the protection of aquatic life designated use as listed in the Missouri WQS was not being met. Low MSCI scores were likely due to nutrient enrichment and possibly low DO that was likely caused by a combination of urban effects, livestock, non-point sources, and the Monett WWTF.

Tests of the null hypotheses resulted in the following conclusions.

- 1) The macroinvertebrate community will not differ among longitudinally separate reaches of Clear Creek. This hypothesis was accepted since all of the test stations during both sampling seasons had MSCI scores of 10 using Ozark/Neosho EDU biological criteria.
- 2) The macroinvertebrate assemblage of Clear Creek samples will be similar to the Ozark/Neosho EDU wadeable/perennial stream biological criteria. This hypothesis was rejected since the all of the samples had MSCI scores that were in the partially supporting range.
- 3) Physicochemical water quality from Clear Creek will meet the WQS of Missouri (MoDNR 2014b). This hypothesis was not accepted since DO was below the WQS of 5 mg/L at two test stations during the fall 2016 sampling season.
- 4) Physicochemical water quality will not differ among longitudinally separate reaches of Clear Creek. This hypothesis was accepted since water constituent results were similar among sampling stations.
- 5) Stream habitat at the Clear Creek sampling stations will be similar to Jones Creek, a candidate reference stream in the Ozark/Neosho EDU. This hypothesis was accepted since the overall stream habitat assessment scores at the sampling stations were at least 75 percent of the Jones Creek score.

7.0 References Cited

- Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. (1999) Rapid bioassessment protocols for use in streams and Wadeable rivers—periphyton, benthic macroinvertebrates, and fish. 2nd Edition, EPA 841/B-99/002, USEPA, Washington DC.
- Broekhuizen, N., S. Parkyn, and D. Miller. 2001. Fine sediment effects on feeding and growth in the invertebrate grazers *Potamopyrgus antipodarum* (Gastropoda, Hydrobiidae) and *Deleatidium* sp. (Ephemeroptera, Leptophlebiidae). *Hydrobiologia* 457:125-132.
- Dyer, S.D., and X. Wang. 2002. A comparison of stream biological responses to discharges from wastewater treatment plants in high and low population density areas. *Environmental Toxicology and Chemistry* 21:1065-1075.
- Evans-White, M.A., W.K. Dodds, D.G. Huggins, and D.S. Baker. 2009. Thresholds in macroinvertebrate biodiversity and stoichiometry across water-quality gradients in Central Plains (USA) streams. *Journal of the North American Benthological Society* 28: 855-868.
- Graham, A.A. 1990. Siltation of stone-surface periphyton in rivers by clay-sized particles from low concentrations in suspension. *Hydrobiologia* 199:107-115.
- Epler, J.H. 2001. Identification manual for the larval Chironomidae (Diptera) of North and South Carolina. <http://esb.enr.state.nc.us/BAUwww/Chironomid.htm>. North Carolina Department of Environment and Natural Resources.
- Jacobsen, R.E. 2008. Midge (Diptera: Chironomidae and Ceratopogonidae) community response to canal discharge into Everglades National Park, Florida. *Proceedings of the 16th International Chironomid Symposium* 13:39-50.
- Lazaro, T.R. 1990. *Urban Hydrology, A Multidisciplinary Perspective*. Lancaster, PA: Technomic Publishing Company.
- Lemly, D.A. 1982. Modification of benthic insect communities in polluted streams: combined effects of sedimentation and nutrient enrichment. *Hydrobiologia* 87:229-245.
- Lenat, D.R., and J.K. Crawford. 1994. Effects of land use on water quality and aquatic biota of three North Carolina Piedmont streams. *Hydrobiologia* 294:185-199.
- Missouri Department of Conservation. 2016. Missouri Pollution and Fish Kills 2015. Aquatic Health Unit, Resource Science Division, 3500 East Gans Road, Columbia, Missouri 65201. 27 pp.

- Missouri Department of Natural Resources. 1999. Total Maximum Daily Loads (TMDLs) for Clear Creek Barry County, Missouri. Water Pollution Control Program, P.O. Box 176, Jefferson City, Missouri 65102. 10 pp.
- Missouri Department of Natural Resources. 2000. Biological Assessment Report. Clear Creek, Barry and Lawrence Counties, 1997 and 2000. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 7 pp.
- Missouri Department of Natural Resources. 2002a. Biological Criteria for Wadeable/Perennial Streams of Missouri. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 32 pp.
- Missouri Department of Natural Resources. 2002b. Stream Survey Sampling Report. Monett Municipal Wastewater Treatment Facility, Clear Creek and Goose Creek, Monett, Missouri, Barry and Lawrence Counties. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri. 3 pp.
- Missouri Department of Natural Resources. 2012. Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 29 pp.
- Missouri Department of Natural Resources. 2014a. Biological Assessment Report. Cave Springs Branch, McDonald County, Missouri and Delaware County, Oklahoma, 2013-2014. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 53 pp.
- Missouri Department of Natural Resources. 2014b. Rules of Department of Natural Resources Division-Clean Water Commission, Chapter 7-Water Quality. 10 CSR 20-7.031 Water Quality Standards. pp. 12-149.
- Missouri Department of Natural Resources. 2015. Standard Operating Procedure MDNR-ESP-113: Flow Measurements in Open Channels. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 16 pp.
- Missouri Department of Natural Resources. 2016a. Standard Operating Procedure MDNR-ESP-002: Field Sheet and Chain-of-Custody Record. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 21 pp.
- Missouri Department of Natural Resources. 2016b. Standard Operating Procedure MDNR-ESP-103: Sample Collection and Field Analysis for Dissolved Oxygen Using a YSI Membrane Electrode Meter, Hach HQ40d LDO probe or YSI Pro ODO probe. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 11 pp.

Missouri Department of Natural Resources. 2016c. Standard Operating Procedure MDNR-ESP-209: Taxonomic Levels for Macroinvertebrate Identifications, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 40 pp.

Missouri Department of Natural Resources. 2016d. Standard Operating Procedure MDNR-ESP-213: Quality Control Procedures for Checking Water Quality Instruments. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 12 pp.

Missouri Department of Natural Resources. 2016e. Standard Operating Procedure MDNR-ESP-214: Quality Control Procedures for Data Processing. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 7 pp.

Missouri Department of Natural Resources. 2016f. Stream Habitat Assessment Project Procedure. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri. 40 pp.

Missouri Department of Natural Resources. 2016g. Stream Survey Sampling Report. Monett Wastewater Treatment Facility, Clear Creek, Monett, Missouri, Barry and Lawrence Counties. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri. 38 pp.

Missouri Department of Natural Resources. 2018a. Standard Operating Procedure MDNR-ESP-001: Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 29 pp.

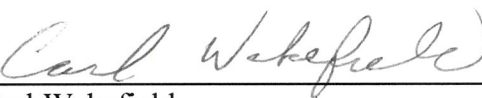
Missouri Department of Natural Resources. 2018b. Standard Operating Procedure MDNR-ESP-012: Analysis of Turbidity Using the Hach 2100p Portable Turbidimeter. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 13 pp.

Missouri Department of Natural Resources. 2018c. Standard Operating Procedure MDNR-ESP-100: Field Analysis of Water Samples for pH. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 8 pp.

Missouri Department of Natural Resources. 2018d. Standard Operating Procedure MDNR-ESP-101: Field Measurement of Water Temperature. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 4 pp.

- Missouri Department of Natural Resources. 2018e. Standard Operating Procedure MDNR-ESP-102: Field Analysis for Specific Conductance. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 9 pp.
- Paul, M.J. and J.L. Meyer. 2001. Streams in the urban landscape. *Annual Review of Ecology and Systematics* 32: 333-365.
- Poulton, B.C., J.L. Graham, T.J. Rasmussen, and M.L. Stone. 2015. Responses of macroinvertebrate community metrics to a wastewater discharge in the Upper Blue River of Kansas and Missouri, USA. *Journal of Water Resource and Protection* 7:1195-1220.
- Simpson, K.W. and R.W. Bode. 1980. Common larvae of Chironomidae (Diptera) from New York State streams and rivers with particular reference to the fauna of artificial substrates. *New York State Museum Bulletin* 439:1-105.
- Sowa, S.P., D.D. Diamond, R.A. Abbitt, G.M. Annis, T. Gordon, M.E. Morey, G.R. Sorensen, and D. True. 2004. Final Report of the Aquatic Component of GAP Analysis: A Missouri Prototype. Missouri Resource Assessment Partnership (MoRAP), University of Missouri. 111 pp.
- Sowa, S., and D. Diamond. 2006. Using GIS and an Aquatic Ecological Classification System to Classify and Map Distinct Riverine Ecosystems Throughout EPA Region 7. Missouri Resource Assessment Partnership (MoRAP), University of Missouri. 242 pp.
- Suckling, D.M. 1982. Organic wastewater effects on benthic invertebrates in the Manawatu River. *New Zealand Journal of Marine and Freshwater Research* 16:263-270.
- United States Environmental Protection Agency. 2000. Ambient Water Quality Criteria Recommendations. Information Supporting the Development of State and Tribal Nutrient Criteria for River and Streams in Nutrient Ecoregion IX. United States Environmental Protection Agency, Office of Water, Washington, D.C., EPA-822-B-00-019. 28 pp.
- Wang, L, D.M. Robertson, and P.J. Garrison. 2007. Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implication to nutrient criteria development. *Environmental Management* 39:194-212.
- Wetzel, R.G. 1983. *Limnology*, 2nd Edition. Saunders College Publishing, Philadelphia, PA 19105.

Submitted by:

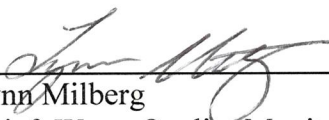


Carl Wakefield
Environmental Specialist
Water Quality Monitoring Section
Environmental Services Program

Date:

12-9-2020

Approved by:



Lynn Milberg
Chief, Water Quality Monitoring Section
Environmental Services Program

LM:cwh

c: Robert Voss, QAPP Project Manager, WPP
Cindy Davies, Southwest Regional Office

Appendix A

Macroinvertebrate Bench Sheets for Clear Creek

Aquid Invertebrate Database Bench Sheet Report

Clear Cr [16037], Station #1, Sample Date: 9/21/2016 12:20:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
BASOMMATOPHORA			
Ancylidae	1		
Lymnaeidae			2
Physella	37	11	65
COLEOPTERA			
Cymbiodyta			1
Dubiraphia			1
Hydrophilidae	1		
Optioservus sandersoni	2		
Psephenus herricki	51	2	
Stenelmis	410	59	10
DIPTERA			
Ablabesmyia		9	
Ceratopogoninae	1		
Chironomidae	4		
Chironomus		32	
Corynoneura	3		1
Cricotopus/Orthocladius	2		
Dasyheleinae	1		
Dicrotendipes	39	130	24
Diptera			2
Forcipomyiinae	10		20
Limonia			8
Myxosargus			1
Paratendipes		3	
Polypedilum flavum	2		
Polypedilum illinoense grp	13		21
Polypedilum scalaenum grp		8	
Procladius		1	
Pseudosmittia			1
Tanytarsus	2		1
Tipula	-99		
EPHEMEROPTERA			
Baetidae	1		
Caenis latipennis		49	3
Stenonema femoratum		1	
Tricorythodes			1
HEMIPTERA			
Belostoma			1
Metrobates			1
Rheumatobates			4

Aquid Invertebrate Database Bench Sheet Report

Clear Cr [16037], Station #1, Sample Date: 9/21/2016 12:20:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
ISOPODA			
Caecidotea (Blind & Unpigmented)		7	
LUMBRICINA			
Lumbricina			2
LUMBRICULIDA			
Lumbriculidae			1
TRICHOPTERA			
Cheumatopsyche	22		
Chimarra	2		
TRICLADIDA			
Planariidae		1	1

Aquid Invertebrate Database Bench Sheet Report

Clear Cr [16036], Station #2, Sample Date: 9/21/2016 10:50:00 AM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
AMPHIPODA			
Hyalella azteca	1		37
BASOMMATOPHORA			
Ancylidae	1	2	4
Lymnaeidae		1	
Physella		2	7
COLEOPTERA			
Psephenus herricki	53	7	
Scirtidae	1		2
Stenelmis	188	18	94
DECAPODA			
Faxonius neglectus	-99		-99
DIPTERA			
Ablabesmyia		14	7
Anopheles			1
Chironomidae		3	2
Chironomus		13	
Corynoneura			4
Cricotopus/Orthocladius		1	1
Dicrotendipes	6	52	2
Nilotanypus			7
Paratanytarsus	1	3	1
Paratendipes		7	
Phaenopsectra	4	17	2
Polypedilum flavum		1	5
Polypedilum illinoense grp	6	20	7
Polypedilum scalaenum grp		23	1
Rheotanytarsus			1
Tanytarsus		75	12
Thienemannimyia grp.			1
EPHEMEROPTERA			
Baetis	126		1
Caenis latipennis	6	127	9
Fallceon	82		7
Stenonema femoratum		3	
Tricorythodes	1	2	11
HEMIPTERA			
Rhagovelia	1		
Rheumatobates		1	
ODONATA			
Argia	8	5	22

Aquid Invertebrate Database Bench Sheet Report

Clear Cr [16036], Station #2, Sample Date: 9/21/2016 10:50:00 AM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Enallagma			9
Hetaerina			1
Libellula		3	
Perithemis	1		
TRICHOPTERA			
Cheumatopsyche	235	1	1
Chimarra	140		
Hydroptila	1		
Triaenodes			1
TRICLADIDA			
Planariidae	13	1	2
TUBIFICIDA			
Tubificidae		4	1

Aquid Invertebrate Database Bench Sheet Report

Clear Cr [16035], Station #3, Sample Date: 9/21/2016 8:50:00 AM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
AMPHIPODA			
Hyalella azteca	1	1	28
BASOMMATOPHORA			
Ancylidae	1	1	2
Physella	8	3	21
COLEOPTERA			
Psephenus herricki	66	1	
Scirtidae			2
Stenelmis	116	18	78
DECAPODA			
Faxonius neglectus	-99		
DIPTERA			
Ablabesmyia	1	18	7
Chironomus		5	2
Dicrotendipes		10	5
Forcipomyiinae		1	
Labrundinia			2
Nilotanypus	2		
Paratanytarsus			2
Paratendipes		2	4
Phaenopsectra		11	10
Polypedilum flavum	37		
Polypedilum illinoense grp	29	14	115
Polypedilum scalaenum grp	5	15	18
Rheotanytarsus	33	1	24
Tanytarsus		15	20
Thienemanniella			1
Thienemannimyia grp.	5		
Zavreliomyia			1
EPHEMEROPTERA			
Baetis	32		
Caenis anceps	1		
Caenis latipennis	2	212	12
Fallceon	68		1
Stenonema femoratum		3	1
Tricorythodes	1	7	19
HEMIPTERA			
Rheumatobates			2
ODONATA			
Argia	9	1	7
Enallagma			7

Aquid Invertebrate Database Bench Sheet Report
Clear Cr [16035], Station #3, Sample Date: 9/21/2016 8:50:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Hetaerina			7
Perithemis	1		
TRICHOPTERA			
Cheumatopsyche	209		2
Chimarra	56		1
Hydroptila			1
TRICLADIDA			
Planariidae	29		3

Aquid Invertebrate Database Bench Sheet Report

Clear Cr [17003], Station #1, Sample Date: 3/15/2017 1:45:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
"HYDRACARINA"			
Acarina		1	
AMPHIPODA			
Stygobromus	2	7	
ARHYNCHOBDELLIDA			
Erpobdellidae		-99	
BASOMMATOPHORA			
Ancylidae	1		
Lymnaeidae	4	-99	
Physella	38	5	58
COLEOPTERA			
Dytiscidae			1
Psephenus herricki		7	
Stenelmis	14	34	25
DIPTERA			
Ablabesmyia		12	
Ceratopogoninae		1	2
Chironomidae	1		
Chironomus		1	1
Corynoneura	4	4	23
Cricotopus bicinctus	3		2
Cricotopus/Orthocladius	224	18	52
Dicrotendipes	5	123	27
Diplocladius			1
Ephydriidae	6		1
Eukiefferiella	114		13
Forcipomyiinae			1
Glyptotendipes	1		
Hydrobaenus	2	26	10
Limnophyes	1		
Micropsectra	13	4	7
Parametriocnemus	16		4
Paraphaenocladius	1		
Paratanytarsus			2
Paratendipes		7	1
Phaenopsectra	1	4	2
Polypedilum aviceps	1		
Polypedilum flavum	8		
Polypedilum illinoense grp	93	1	48
Polypedilum scalaenum grp		12	
Procladius		1	

Aquid Invertebrate Database Bench Sheet Report

Clear Cr [17003], Station #1, Sample Date: 3/15/2017 1:45:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
Pseudosmittia			2
Sciomyzidae	1	1	2
Smittia			2
Tanytarsus	6	17	3
Thienemanniella	3		10
Tipula	1		
EPHEMEROPTERA			
Caenis latipennis		145	2
Fallceon	1		
Stenonema femoratum		2	
ISOPODA			
Caecidotea (Blind & Unpigmented)		2	1
LUMBRICINA			
Lumbricina	1		
ODONATA			
Argia		1	
TRICHOPTERA			
Cheumatopsyche	28	1	1
Chimarra	1	1	
Ironoquia			1
Polycentropus		-99	
TRICLADIDA			
Planariidae	8	5	
TUBIFICIDA			
Enchytraeidae			2

Aquid Invertebrate Database Bench Sheet Report

Clear Cr [17002], Station #2, Sample Date: 3/15/2017 12:40:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
AMPHIPODA			
Hyalella azteca			18
BASOMMATOPHORA			
Ancylidae			4
Physella	1	62	32
COLEOPTERA			
Psephenus herricki	2	1	
Stenelmis	53	19	13
DECAPODA			
Faxonius neglectus	-99		
DIPTERA			
Ablabesmyia		19	4
Chironomus		4	
Corynoneura		3	6
Cricotopus bicinctus	2	3	8
Cricotopus trifascia	28		
Cricotopus/Orthocladius	125	36	79
Dicrotendipes	1	99	49
Eukiefferiella	52	2	
Hydrobaenus		2	3
Micropsectra	3	1	7
Parakiefferiella			1
Parametriocnemus	5		
Paratanytarsus		2	13
Paratendipes		14	
Phaenopsectra		3	10
Polypedilum flavum	21		
Polypedilum illinoense grp	4	1	12
Polypedilum scalaenum grp		41	
Rheotanytarsus	5		
Simulium	12		
Tanytarsus	6	25	19
Thienemanniella	23	9	36
Thienemannimyia grp.		1	1
Tvetenia bavarica grp	1		
EPHEMEROPTERA			
Acentrella			1
Baetis	14		
Caenis latipennis	2	176	6
Fallceon	35		
Stenonema femoratum	1	3	

Aquid Invertebrate Database Bench Sheet Report

Clear Cr [17002], Station #2, Sample Date: 3/15/2017 12:40:00 PM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
HEMIPTERA			
Belostoma			-99
ODONATA			
Argia	5	1	8
Corduliidae	1		
Enallagma			4
TRICHOPTERA			
Cheumatopsyche	130		1
Chimarra	21	1	
Hydropsyche	1		
Hydroptila		1	4
TRICLADIDA			
Planariidae	112	5	1
TUBIFICIDA			
Tubificidae		2	

Aquid Invertebrate Database Bench Sheet Report

Clear Cr [17001], Station #3, Sample Date: 3/15/2017 11:30:00 AM

CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
AMPHIPODA			
Hyalella azteca			21
BASOMMATOPHORA			
Physella	4	9	4
COLEOPTERA			
Psephenus herricki	8	2	
Stenelmis	28	38	43
DIPTERA			
Ablabesmyia		14	2
Chironomus		2	1
Corynoneura	1	1	
Cricotopus bicinctus	31	8	6
Cricotopus trifascia	7		
Cricotopus/Orthocladius	34	21	4
Dicrotendipes	2	176	13
Eukiefferiella	6		
Hydrobaenus		6	
Labrundinia		5	
Limnophyes			1
Micropsectra	2	1	6
Nilotanytus			2
Parametriocnemus			3
Paraphaenocladius			1
Paratendipes		1	
Phaenopsectra	1	2	3
Polypedilum aviceps	1		
Polypedilum flavum	88		75
Polypedilum illinoense grp	2	1	10
Polypedilum scalaenum grp		9	
Rheotanytarsus	73	2	32
Tanytarsus	2	6	4
Thienemanniella	110	4	21
Thienemannimyia grp.	1		2
Tipula			-99
EPHEMEROPTERA			
Baetis	5		
Caenis latipennis	1	120	1
Fallceon	17		1
Stenonema femoratum		1	
LEPIDOPTERA			
Petrophila	1		

Aquid Invertebrate Database Bench Sheet Report
Clear Cr [17001], Station #3, Sample Date: 3/15/2017 11:30:00 AM
CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence

ORDER: TAXA	CS	NF	RM
ODONATA			
Argia	5	2	7
Calopteryx		-99	1
Hetaerina			1
Libellulidae	-99		
RHYNCHOBDELLIDA			
Glossiphoniidae		1	
TRICHOPTERA			
Cheumatopsyche	109	-99	34
Chimarra	8		
Hydropsyche	1		
Hydroptilidae			1
Oecetis		1	
TRICLADIDA			
Planariidae	114	17	32
TUBIFICIDA			
Enchytraeidae			1
Limnodrilus hoffmeisteri			1